Life History Characteristics of Freshwater Fishes Occurring in the Northwest Territories and Nunavut, with Major Emphasis on Riverine Habitat Requirements

C.L. Evans[1], J.D. Reist[1] and C.K. Minns[2]

[1] Department of Fisheries and Oceans, Arctic Fish Ecology and Assessment Research, Central and Arctic Division, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6 Canada

[2] Department of Fisheries and Oceans, Great Lakes Laboratory of Fisheries and Aquatic Sciences, Bayfield Institute, 867 Lakeshore Road, P.O. Box 5050, Burlington, Ontario, L7R 4A6 Canada.

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by

C.L. Evans[1], J.D. Reist[1] and C.K. Minns[2]

1. Department of Fisheries and Oceans, Arctic Fish Ecology and Assessment Research, Central and Arctic Division, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6 Canada

2. Department of Fisheries and Oceans, Great Lakes Laboratory of Fisheries and Aquatic Sciences, Bayfield Institute, 867 Lakeshore Road, P.O. Box 5050, Burlington, Ontario, L7R 4A6 Canada.

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ABSTRACT

An intensive literature review was undertaken to summarize what is currently known about fish use of freshwater habitats in the Northwest Territories and Nunavut. A previous report summarized the lacustrine habitat requirements, thus this report focuses on species that use riverine environments for a portion of their life history. Habitat preferences for physical features such as water depth, substrate type, cover useage, and water quality were rated as nil, low, medium, or high. Of the 46 species in this area, information was sufficient to complete 43 habitat tables for four stages of development (eggs, young-of-the-year, juveniles and adults). A summary of the life history, distribution and habitat requirements for each species can be found in the text. Initially, comparisons of fish habitat utilization were to be made across the different ecoregions of the Northwest Territories and Nunavut, however, the lack of studies which have examined riverine habitat in this area precluded this. This study along with the previous lacustrine report has outlined the substantial data gap that exists in our current understanding of northern freshwater fish species and indicates further studies must be performed.

RÉSUMÉ

On a réalisé une revue détaillée de la documentation scientifique pour faire la synthèse des connaissances actuelles sur l'utilisation des habitats d'eau douce par les poissons dans les Territoires du Nord-Ouest et le Nunavut. Dans un rapport précédent, on avait établi les exigences des poissons relatives aux habitats lacustres. Le présent rapport porte sur les espèces qui exploitent des milieux fluviaux durant une partie de leur cycle vital. On a catégorisé les préférences en matière d'habitat quant à des paramètres physiques comme la profondeur de l'eau, le type de substrat, le couvert et la qualité de l'eau au moyen des cotes suivantes : nulle, faible, moyenne ou forte. Avec l'information disponible, on a pu établir un tableau de l'habitat de quatre stades de développement (œuf, jeune de l'année, juvénile et adulte) de 43 des 46 espèces présentes dans la région. Pour chaque espèce, un sommaire du cycle vital, de la répartition et des exigences en matière d'habitat est présenté. Au départ, on voulait effectuer des comparaisons en ce qui a trait à l'utilisation de l'habitat par les poissons pour l'ensemble des écorégions des Territoires du Nord-Ouest et du Nunavut, mais trop peu d'études ont été réalisées sur les habitats fluviaux de cette région pour le permettre. La présente étude et le rapport précédent sur les habitats lacustres ont mis en lumière des lacunes substantielles dans les données et donc dans nos connaissances actuelles sur les espèces de poissons dulcicoles du nord, d'où la nécessité de mener de nouvelles études.

INTRODUCTION

The need to protect fisheries habitat is essential to the conservation of freshwater fish, since each fish species follows a certain life history pattern which may utilize many different habitat types. The habitats will vary spatially and temporally as fish grow, mature, and spawn. Each specific habitat in which a freshwater fish spawns, rears, feeds, and overwinters must be managed appropriately to enhance survival. The first step in proper management is knowledge of habitat use by specific life history stages of each fish species. The focus of this report is on the lotic or flowing water habitat that adfluvial, fluvial, and anadromous fish species utilize in the Northwest Territories (NT) and Nunavut (NU). The selection of habitat by a certain fish species is not based entirely on physical features alone. It can be affected by the presence of other fish species, weather patterns, distribution of prey and water temperatures, and other limnological factors. Managers when assessing impacts on fish habitat need to take into consideration all habitat types, as they are used by all of life history stages of the fish species in question, to ensure minimal impact to the population.

Physical features that are important to fish include depth, substrate type, cover, water velocity, and water clarity. Most freshwater fish are concentrated in the shallow areas of lotic environments along the banks, but some do prefer the middle of the channel and or benthic habitats. They usually choose even shallower habitats in the spring or fall in which to spawn. Substrate type during spawning is usually chosen to ensure the survival of the eggs. This differs for times outside of spawning season as substrate type usually corresponds with needs for shelter and feeding. Cover also plays an important role as it provides shelter from predators and from environmental conditions, and also provides cover for ambushing prey. Young fish tend to occupy areas of the lotic environment with zero to slow currents and tend to move into moderate and fast currents as they grow. Typically, adult fish occupy very different habitats than do young-of-the-year (YOY) fish, with juvenile fish falling somewhere in between the two extremes. Freshwater fish and anadromous fish undergo seasonal migrations, and those fish that do not migrate great distances may undergo daily migrations. For example preferred water depth of a fish may show a diurnal pattern that is affected by water temperature and light intensity among other factors. These changes in habitat use during a species' life cycle make it important to manage for survival of all life history stages.

This document is a summary of physical riverine habitat requirements of various life history stages of freshwater and anadromous fish in the Northwest Territories and Nunavut. Since there is very little information on arctic fish habitat much of the information regarding habitat preferences was extrapolated from other areas of the species' range within North America. These gaps should be filled with more study or could be extrapolated from lacustrine requirements (see Richardson *et al.* 2001). There is also a certain amount of literature that may exist that was not covered in this review, and so therefore the authors acknowledge some studies may have been overlooked. It is also

important to note that our assessment of the degree of association between a species and a particular habitat was subjective and thus qualitative in nature.

METHODS

This report includes all species of fishes known to occur in riverine freshewater habitats of the Northwest Territories and Nunavut (Table 1). Much of the following method parallels that in Bradbury *et al.* (1999) and Richardson *et al.* (2001). An extensive literature search was performed to collect all available information of riverine habitat use by fresh water fish species throughout various stages of their life histories. Databases searched included:

- various reference texts including Scott and Crossman 1973; McPhail and Lindsey 1970; Morrow 1980; Becker 1983; and Scott and Scott 1988
- DFO (Central and Arctic Region) publications and scientific reports
- DFO WAVES database
- Fisheries and Aquatic Sciences Abstracts (1970-Present)
- Biological Abstracts, Current Contents and Netdoc databases at the University of Manitoba
- various Habitat Suitability Index (HSI) models published by the U.S. Fish and Wildlife Service, Biological Services
- Nunavut Environmental Database

Each fish species was grouped into one of the following life history types based on its utilization of various habitat types for spawning, rearing, growth, feeding, and maturation (Table 2).

The following life history types as developed by Richardson *et al.* (2001) and as applicable to riverine fish species were used:

(1) Lacustrine: those species which spawn, rear and remain in lake environments for the majority of their life cycle.
   (a) Adfluvial: those populations of fish which rear and remain in lacustrine environments for the majority of their life cycle, but which spawn in rivers or streams associated with lakes.

(2) Riverine: those fish species which spawn, rear and remain in river or stream environments for the majority of their life cycle.
   (a) Fluvial: those species which spawn and rear in the same section of a stream or river making only minor migratory movements (e.g., <300km) throughout their life time.
   (b) Stream-resident: those species which spawn and rear in the same section of a stream and are prevented from any migratory movements due to physical barriers or choose not to migrate (e.g., <30km).

(1) Anadromous: those fish species which spawn in freshwater environments and migrate to marine environments for a portion of their life cycle.

A brief summary of the life history of all the riverine and anadromous fish in Nunavut and the Northwest Territories is given with the emphasis on lotic habitats utilized for at least a portion of their life cycle. The life cycle was broken down into a) spawning, b) YOY, c) juvenile, and d) adult phases. Habitat requirements were reported on the basis of four physical habitat features: i) water depth, ii) substrate type, iii) structure/cover, and iv) water quality.

Water Depth

Five water depth categories were employed: 0-20, 21-60, 61-100, 101-200, and > 200 cm.

Substrate Type

Substrate composition was reported as stated in the reference, however if particle size was provided, substrate type was classified according to Scruton *et al.* (1992).

Structure/Cover

Cover was defined as any feature within the aquatic environment that may be used by fish for protection from predators, competitors and adverse environmental conditions. Cover may also provide spawning habitat for some species (e.g., Cyprinids) and as camouflage for predatory fish.

The following categories were used to define cover

- submergent vegetation – aquatic plants that grow wholly under the water's surface (e.g., Elodea, pondweeds, bladderwort, pipewort) and including mosses and algae.
- emergent vegetation – all aquatic plants which grow on water-saturated or submerged soils and extend their stems and leaves above the surface of the water (e.g., cattails, grasses, sedges and rushes).
- overhead – riparian cover overhanging the littoral zone, undercut banks and woody debris at the surface of the water.
- in situ – rocks and boulders on sand gravel substrates, submerged woody debris, etc.
- other – any type of cover not included in the above categories.

Water Velocity

Water velocity was grouped into the following categories as defined by Portt *et al.* (1999): Pool $\leq$0.25m/sec; Run >0.25-$\leq$0.5 m/sec; Riffle >0.5-$\leq$1.00 m/sec; Rapid >1.00 m/sec.

Water Quality

Two categories for water quality were used, clear and turbid. Statements in the references were used to judge the degree of preference that fish had for these two categories and an appropriate rating was given.

The degree of association between a given species and these habitat features was reported in tabular format (Tables 3-47) using a rating system as follows: high (species is nearly always associated), medium (species is frequently associated), and low (species is infrequently associated).

Cases where no information was available to indicate that a species utilizes a particular habitat feature were left blank. All references were assigned a numerical value for ease of representation and can be found in the abridged reference list for tables on p. 163. These and non-numeric references in the summary section of the report are listed on p. 74.

Each species was also associated with the freshwater ecoregions in which it occurs. Ecoregions were defined by Canadian Drainage Basins and Abell *et al.* (2000)(Fig. 1, Table 2). These ecoregions were based on watershed divisions and are described below. The initial intent was to compare habitat useage across ecoregions to determine if changes in ecoregions affected species habitat requirements. This comparison was not feasible since there was a lack of habitat information for these fish species for the various ecoregions in the NT and NU. Given the significant differences in ecoregions with latitude in the north, the fact that many of the fish species occupy several ecoregions, and that habitat associations likely shift to some degree latitudinal for such species, this lack of knowledge is a serious short coming for proper assessment and management. Appropriate comparative studies are necessary.

The ecoregions are

Upper Mackenzie – this ecoregion extends from the northern borders of Alberta and Saskatchewan and includes the area directly south of the Great Slave Lake, including the Slave and Taltson rivers.

Lower Mackenzie – this ecoregion extends from the northern border of British Columbia and Alberta and includes the lower portion of the Mackenzie River and all its tributaries southwest of Great Slave Lake. Great Bear Lake is included in this ecoregion along with the Peel, Arctic Red, Ramparts, Keele and Liard rivers. The Mackenzie River waters are typically warm and muddy while most of its tributaries are cold and clear.

North Arctic – this ecoregion lies entirely along the extreme northern mainland of the Northwest Territories and Nunavut and includes some larger rivers such as the Back, Burnside, Coppermine, Hornaday and Anderson.

East Arctic – this ecoregion extends from the northern border of Manitoba, through the eastern mainland portion of Nunavut, and continues south along the western shore of Baffin Island to include rivers draining into Foxe Basin. The western border of this

ecoregion is defined by the western portion of the Thelon River. All the islands of Hudson, James and Ungava bays are included in this ecoregion. The major rivers are the Thelon, Thlewiaza and Tha-anne.

Western Arctic Islands – this ecoregion includes all of Banks, Victoria, Melville, Prince of Wales, Somerset islands and the surrounding smaller islands along with the western portions of Ellesmere, Devon and Baffin islands.

Eastern Arctic Islands – this ecoregion includes the eastern portions of Ellesmere, Devon, and Baffin islands with rivers draining into Nares Strait, Baffin Bay and Davis Strait.

RESULTS

A total of forty-six fish species are reported to occur in freshwater environments of the Northwest Territories and Nunavut. Of these there are forty-three that are known to utilize lotic environments at some point in their life cycle. Fifteen of these are anadromous and thirty-four are riverine. Many species will display more than one life history type, that is, exhibit for example a riverine and anadromous life history. The common and scientific names of fish species cited in this report generally follows that of Robbins *et al.* (1991). The shortjaw cisco, deepwater sculpin and fourhorn sculpin occur exclusively in lakes and are not included in this summary. The darktail lamprey is not listed in Robbins *et al.* (1991) and is still undergoing work to determine its status as a species (Claude Renaud, Canadian Museum of Nature, personal communication), and is therefore also not included in this summary.

The following is a summary of the major life history stages of all freshwater fish species occurring in the NT and NU and their habitat requirements with major emphasis on riverine environments. The fish are grouped according to family and then within the family listed in alphabetical order by scientific name.

Lampreys (Petromyzontidae)

Arctic lamprey (*Lampetra camtschatica* (Tilesius, 1811))

The Arctic lamprey occurs in arctic drainages of the Bering Sea south to Alaska and east along the Yukon and Northwest Territories. They are the most widely distributed species of Holarctic lamprey. They are common in both freshwater and marine environments in NT but not reported to exist in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Vladykov and Kott 1979; Lee *et al.* 1980). In NT they occur from the mouth of the Mackenzie River upstream to Great Slave and Artillery lakes and to Fort Smith on the Slave River (McPhail and Lindsey 1970; Nursall and Buchwald 1972; Scott and Crossman 1973; Lee *et al.* 1980). They are also reported to occur in the Anderson River, as well as the Salt River and various other tributaries of the Mackenzie River system (Scott and Crossman 1973; Bond and Erickson 1991, 1992; Stewart 1996a, 1996b, 1997, 1999, 2000).

Ecoregions - The Arctic lamprey is found in rivers and lakes in the Lower Mackenzie, Upper Mackenzie and North Arctic ecoregions. Ammocoetes are typically not found in clear rivers with rocky bottoms, they prefer rivers with silty mud bottoms and higher turbidity (Nursall and Buchwald 1972).

The life history of the Arctic lamprey is largely unknown and poorly studied. They exhibit anadromous, fluvial and adfluvial life history types. Adults can be either parasitic or non-parasitic (Heard 1966; McPhail and Lindsey 1970; Nursall and Buchwald 1972). Parasitic adults, after completing metamorphosis from ammocoetes, feed on the blood of fishes and cetaceans. Most parasitic species are anadromous but some remain in freshwater all their lives. Non-parasitic adults, after completing metamorphosis from ammocoetes, can not feed due to the absence of a functional intestinal tract. All non-parasitic species live exclusively in freshwater (Vladykov and Kott 1979).

Spawning takes place in late May and early July in rivers (e.g., Hay, Mackenzie and Slave rivers)(Walters 1955; Heard 1966; Buchwald 1968; Nursall and Buchwald 1972). Spawning occurs over a gravel stream bottom after which the adults die (Buchwald 1968; Nursall and Buchwald 1972). Water temperature at spawning was recorded as 12.2-15.0°C. The nests are built in sandy areas of riffles by both sexes thrashing their anchored body and moving individual stones (Heard 1966; Buchwald 1968; Scott and Crossman 1973). In Alaska spawning took place away from the main current, in water from 7.62-20.32 cm deep, flowing from 0.15-0.30 m/sec, on gravel from 1.3-5.0 cm in diameter (Heard 1966).

The eggs hatch a few weeks after spawning and ammocoete larvae drift down stream passively into areas of eddies and backwaters. They are found in beds of silty mud in quiet backwaters along the edges of rivers where they can burrow. They are seldom found on sand or gravel bottom. Ammocoetes can not make progress against any strong current. After a number of years (3-4) in the natal stream and a slow migration over those years down river the transformation (metamorphosis) of the ammocoetes begins in late summer (August and September) and continues over the winter (Buchwald 1968; Nursall and Buchwald 1972).

Immature adults disperse into lakes (adfluvial), rivers (fluvial) and to the ocean (anadromous) in late spring and early summer (May to July). Parasitic adults prey on lake whitefish, cisco, inconnu, lake trout, and longnose sucker. These adults are caught in late August and September by fisherman in Great Slave Lake and are rarely caught in winter, suggesting that they do not feed in the winter. Instead they move back towards their spawning rivers. In the spring the mature adults move into the streams to spawn . In Great Slave Lake adults live for one year and die after they spawn, giving them a life span of five years (Vladykov and Kott 1979; Buchwald 1968; Nursall and Buchwald 1972). For lacustrine habitat information for the adult Arctic lamprey refer to Richardson *et al.* (2001). Anadromous species may undergo long migrations to the spawning grounds (Vladykov and Kott 1979). No information exists for the fluvial life history type, although it is suggested that populations may exist in the Mackenzie, Hay and Slave

rivers (Buchwald and Nursall 1972). These non-parasitic lampreys mature quickly, spawn and then die.

Salmonids (Salmonidae)

Lake cisco (*Coregonus artedi* (Le Sueur 1818))

The lake cisco has the most extensive North American distribution of any cisco. It is found in lakes in the north-central and eastern United States, from eastern Quebec, through the Great Lakes system and in Ontario, Manitoba, Saskatchewan, Alberta, Nunavut and the Northwest Territories (Scott and Crossman 1973). Lake cisco are present from the western Hudson Bay coast of NU to the Mackenzie River system in the NT, as far north as Great Bear Lake and south to the border of Alberta (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). A single specimen from Baffin Island (Bernier Bay) was reported by Ellis (1962). The lake cisco is primarily a lacustrine species but may be found in larger rivers in the NT and NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). For a description of lacustrine habitat requirements and life history for the lake cisco please refer to Richardson *et al.* (2001).

They exhibit a lacustrine life history but anadromous life histories occur in areas outside of the NT and NU (James Bay - Quebec) (Scott and Crossman 1973; Morin *et al.* 1981). In Hudson Bay the lake cisco can enter salt water and occurs in ponds on many of the islands (Scott and Crossman 1973). A dwarf form of the lake cisco exists but literature does not report it selecting a different habitat than the normal form (Shields and Underhill 1993) and will therefore not be separated when discussing habitat requirements.

Ecoregions – The lake cisco is found in the Lower Mackenzie, Upper Mackenzie, East Arctic, North Arctic and West Arctic Island ecoregions.

Spawning is reported to primarily occur in lakes during the fall (Scott and Crossman 1973) but McLeod *et al.* (1976) reported large concentrations of lake ciscoes at the mouth of the Thelon River during mid-November. In this area there is a considerable amount of coarser sand, gravel and cobble that could provide suitable spawning habitat. Also lake ciscoes were caught in the Thelon River 11 km from the mouth. They were taken from a pool area of the river which is separated from Baker Lake by areas of rapids. River spawning runs have also been reported in Wisconsin (Becker 1983). Rivers are not normally considered as lake cisco habitat.

Most of the reports of lake cisco in rivers in the NT and NU have resulted from surveys of polar gas pipeline routes (McLeod *et al.* 1976; Hatfield *et al.* 1977), arctic land use programs (MacDonald and Stewart 1978, 1980; Sutherland and Golke 1978), or reviews of fish stocks (Stewart 1996a, 1996b, 1997,1999; Stewart and Low 2000). The function the rivers serve as habitat is unknown and should be further studied. Due to this lack of information no river habitat requirement table for the lake cisco is given.

Arctic cisco (*Coregonus autumnalis* (Pallas 1776))

The Arctic cisco has a circumpolar distribution occurring in Russia, Siberia, Alaska and Canada (Scott and Crossman 1973; Lee *et al.* 1980). In Canada it occurs in rivers, lagoons, coastal beaches and stream mouths along the Beaufort Sea coast from the Yukon North Slope to Bathurst Inlet in NU, and ascends into the Mackenzie River as far south as the Liard River (Scott and Crossman 1973; Craig and Mann 1974; Lee *et al.* 1980; McLeod and O'Neil 1983; Dillinger *et al.* 1992). The Arctic cisco is anadromous in North America, but landlocked populations are known to exist in Russia and Ireland (Lee *et al.* 1980). It is also thought that there may be a non-anadromous population in the Liard River but this has not been confirmed (Dillinger *et al.* 1992). As currently understood all populations of Arctic cisco that occur in and west of the Mackenzie River along the northern coast (including those found along north slope Alaska) originate from spawning stocks within the Mackenzie River system (Gallaway *et al.* 1983; Fechhelm and Griffiths 1990). Those which occur along the Tukyoyaktuk Peninsula also originate from the Mackenzie River. Populations of Arctic cisco that occur east of the Mackenzie River may originate from spawning stocks in the Anderson, Miner and Kugaluk rivers, but spawning in these rivers has not been confirmed. Also there may be some contribution from the Mackenzie River to these stocks.

Ecoregions – Arctic cisco occur in the Lower Mackenzie (Arctic Red, Peel, Rampart, Liard and Mackenzie rivers), North Arctic (Simpson, Western, and Back rivers) and West Arctic Islands (Cambridge Bay) ecoregions. Arctic cisco occur along the coast in brackish and marine waters and enter freshwater to spawn and overwinter. Both adults and juveniles overwinter in freshened coastal areas associated with the mouths of rivers which flow throughout the year. Juveniles appear to use freshwater areas as nurseries as well.

Spawning occurs in the Mackenzie River system with Arctic cisco entering the river in late June and spawning in tributaries during late September and early October (Wynne-Edwards 1952; Scott and Crossman 1973; Lee *et al.* 1980; Chang-Kue and Jessop 1991; Dillinger *et al.* 1992; Jessop and Chang-Kue 1993). Tributaries of the Mackenzie River that are used for spawning include the Peel, Arctic Red, Great Bear, Mountain and Carcajou rivers (Hatfield *et al.* 1972; Stein *et al.* 1973; Dillinger *et al.* 1992). Arctic cisco travel great distances to the spawning grounds in many cases. In the Peel River the Arctic cisco upstream migration starts in mid-July with the fish arriving in mid-August on the spawning grounds. The Arctic Red River has a split migration run, one run from late June to early July and another from mid-September to October (Dillinger *et al.* 1992). Arctic cisco are also thought to spawn in the Anderson River and begin to return to the river to spawn in late August (Bond and Erickson 1992b). Spawning takes place in fast water, with the eggs being scattered over the gravel substrate (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Dillinger *et al.* 1992). Adults prefer less turbid water to spawn in, compared to the water in which they are normally found (Dillinger *et al.* 1992).

The eggs hatch in the spring under the ice and the young are thought to stay in the vicinity of the spawning beds, feeding until ice out (Hatfield *et al.* 1972). The young reach the

Mackenzie River in late spring and are swept downstream out into the delta. They then move both east and west along the northern coastline (Fechhelm and Fissel 1988; Reist and Bond 1988; Fechhelm and Griffiths 1990). Young-of-the-year from the Mackenzie River system can rear in Canadian waters where they disperse along the Tuktoyaktuk Peninsula (Liverpool and Wood bays)(Byers and Kashino 1980; Bond 1982; Hopky and Ratinski 1983; Lawrence *et al.* 1984; Reist and Bond 1988; Bond and Erickson 1993). They have also been found foraging in shallow lakes of the Mackenzie Delta in June (Hatfield *et al.* 1972) and YOY are abundant in the Anderson River mouth in early July (Bond and Erickson 1991, 1992b). Others disperse along the coast as far west as the Alaskan north slope to the mouths of freshwater rivers and other coastal areas (Gallaway *et al.* 1983; Fechhelm and Fissel 1988; Moulton 1989; Fechhelm and Griffiths 1990). Young-of-the-year Arctic cisco are caught nearshore during their westward migration in July at Phillips Bay, Yukon (Bond and Erickson 1987) and reach Prudhoe Bay, Alaska by late August (Bond and Erickson 1989). They spend their first summer feeding in nursery areas in the delta or in lagoons and shallow coastal areas along the Alaskan coast (Gallaway *et al.* 1983). Healthy age 0 Arctic cisco can be found along the Alaska coast offshore beyond the brackish water zone (Jarvela and Thorsteinson 1999) demonstrating that this species smoltifies at a young age compared to other anadromous arctic coregonines.

After migrating to a suitable nursery area Arctic cisco will remain there as juveniles for many years until they mature usually at about age 7-8 (Gallaway *et al.* 1983; Bond and Erickson 1987, 1989). Juvenile Arctic cisco are found in brackish to near marine environments during the summer. These areas contain water which is shallow, relatively warm and turbid (Craig 1984). Arctic cisco are usually found nearshore but some ciscoes have been caught almost 30 km offshore of Herschel Island in mid-water trawls (Galbraith and Hunter 1975). Little is known about overwintering areas in Canada. It is believed that YOY Arctic cisco overwinter in the Anderson River (Bond and Erickson 1991, 1992b). In Alaska YOY and juveniles use the lower deltas of Alaskan rivers (Colville or Sagavanirktok) as overwintering locations (Gallaway *et al.* 1983; Bond and Erickson 1987, 1989).

After spawning, adult Arctic cisco move back down the Mackenzie River during October to December (Stein *et al.* 1973; Lee *et al.* 1980; Dillinger *et al.* 1992). They occur in the lower reaches of large muddy rivers, and are commonly taken in brackish waters (McPhail and Lindsey 1970). Adult Arctic cisco are found in both nearshore and offshore coastal areas (Bond 1982; Hopky and Ratynski 1983). Adult Arctic cisco were most abundant in the Tuktoyaktuk Harbour area from late July to August with large movements of cisco into the southern area of the harbour in late August (Bond 1982; Hopky and Ratynksi 1983) signifying the return migration of pre-spawning ciscoes to the Mackenzie River. Juveniles and non-spawning adults remain in the outer delta and along the coast throughout the fall (Percy 1975). Off the coast of Alaska, Arctic ciscoes utilized areas of the coast with water temperatures ranging from 1.2-7.4°C, and were most common in the uppermost 6m of the water column (Jarvela and Thorsteinson 1997). In Siberia adults mature between age 5-10 years of age depending on the river they reside in, and are not known to spawn every year (McPhail and Lindsey 1970; Scott and Crossman

1973). Arctic cisco off the Yukon coast mature at age 7 and do not spawn each year (Craig and Mann 1974). In Tuktoyaktuk Harbour the youngest mature male Arctic cisco was eight years of age, while the youngest mature female Arctic cisco was six years of age (Bond 1982). Most authors agree that Arctic ciscoes mature between six and ten years of age (Stein *et al.* 1973; Craig and Mann 1974; Griffiths *et al.* 1975; Bond 1982). Adults can reach ages as old as 20 to 24 (Craig and Mann 1974; Bond and Erickson 1991, 1992a).

Lake whitefish (*Coregonus clupeaformis* (Mitchill 1818))

The lake whitefish complex includes lake whitefish (*C. clupeaformis*), the Alaskan whitefish (*C. nelsoni*) and the humpback whitefish (*C. pidschian*) all of which will be treated as one topic. In Canada the lake whitefish occurs from the Atlantic coastal watersheds, west through Quebec (including Ungava Bay), Ontario (including the Great Lakes), Manitoba (including coastal drainages in Hudson Bay), Saskatchewan (mostly northern waters), Alberta and British Columbia (Scott and Crossman 1973). Lake whitefish also occur throughout the NT and NU. The northern limit is southern Banks Island in the NT with whitefish being found from southern Victoria Island to the Keewatin District in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Babaluk *et al.* unpublished data).

Lake whitefish occur in lakes but can also be found in larger rivers and brackish waters (McPhail and Lindsey 1970; Scott and Crossman 1973). They exhibit lacustrine, adfluvial and anadromous life history types (Scott and Crossman 1973; Tripp *et al.* 1981; Reist and Bond 1988), and it has been suggested that riverine populations may exist but this has not been confirmed. These life history types and related associations with particular types of water bodies may correspond with particular taxa which make up the complex. More work is required to address this issue. Dwarf forms of lake whitefish have been described in lacustrine populations but have not been described for riverine or anadromous life history types. For a description of lacustrine habitat requirements refer to Richardson *et al.* (2001). Anadromous populations spawn in rivers (Stein *et al.* 1973; Sturm 1988) as do adfluvial populations (Scott and Wheaton 1954; McCart 1982; Roberge *et al.* 1985; Patalas 1993). Most of the biological studies on lake whitefish in northern Canada have been conducted in the Mackenzie River drainage. There is very little information concerning other northern populations in Canada.

Ecoregion – The lake whitefish is found in the Upper Mackenzie, Lower Mackenzie, North Arctic, East Arctic, and Western Arctic Island ecoregions.

Anadromous

In northern Canada, anadromous lake whitefish are known to spawn in the Mackenzie River and its tributaries. In this area lake whitefish spawn in late September and early October (Stein *et al.* 1973; Jessop *et al.* 1974). The upstream run of lake whitefish along the main stem of the Mackenzie River and in major delta channels occurs by mid-September (Stein *et al.* 1973). Spawning aggregations have been recorded at the mouth of

the Arctic Red River during October, with spawning taking place in water temperatures of 1.0 to 1.5°C (Stein *et al.* 1973; Jessop and Lilley 1975). In Alaska at the onset of ice breakup mature adults migrate upstream to feed in lakes and riverine sloughs, and continue slowly to the spawning grounds (Sturm 1988). Substrate used for spawning consists of stone or hard silt substrate (Percy 1975). The eggs hatch during late winter or early spring (McPhail and Lindsey 1970). In Alaskan rivers spawning occurs from mid-September to mid-November depending on the river in question (Alt 1979; Sturm 1988). Incubation time for the eggs in Alaska varies between 107-231 days (Auer 1982). Spawning occurs in the shallows of rivers, in moderately swift current, and at depths of 0.5 to 2.5 m over gravel or sand bottoms (McPhail and Lindsey 1970; Alt 1979). No nests or redds are constructed, eggs are broadcast over the substrate with fertilized eggs lodging in the crevices of the substrate (Alt 1979, Morrow 1980).

After hatching fry are swept down by spring runoff reaching the Mackenzie Delta by late May or June (Hatfield *et al.* 1972; Taylor *et al.* 1982). The delta lakes and channels, inner and outer estuary, coastal areas and back eddies of the Mackenzie River are the primary nursery areas utilized by young lake whitefish (Jessop *et al.* 1974; Jessop and Lilley 1975; Bond and Erickson 1985; Reist and Bond 1988). Young were first seen in Wood Bay in mid-July (Bond and Erickson 1991). Juvenile lake whitefish migrate to and utilize the freshwater drainages of the Tuktoyaktuk Peninsula (Mayogiak, Kukjuktuk and Freshwater systems) for feeding, rearing and overwintering (Lawrence *et al.* 1984; Bond and Erickson 1982, 1985; Chang-Kue and Jessop 1992). They may stay in these freshwater systems for a few years to grow or may migrate back to the coast and eventually back to the delta (Chang-Kue and Jessop 1992). Lake whitefish are closely associated with the Mackenzie Delta until they are approximately four years of age when they may wander further along the coast (Kendel *et al.* 1975; Lawrence *et al.* 1984).

After spawning the adults in the Mackenzie River migrate downstream during late fall (October to early November) to overwinter in the Mackenzie Delta, the freshwater inner estuary, lakes of Tuktoyaktuk Peninsula or Richardson Island, Tuktoyaktuk Harbour and Kugmallit Bay (Stein *et al.* 1973; Jessop and Lilley 1975; Percy 1975; Bond 1982; Lawrence *et al.* 1984). Adult lake whitefish have also been caught in the Liard, Rabbitskin and Peel rivers during winter suggesting that these rivers provide overwintering areas. These lake whitefish were caught in water depths from 0.6 to 20 m (Jessop and Lilley 1975).

Although considered anadromous, lake whitefish from the southeastern Beaufort Sea seldom migrate far from the mouth of the Mackenzie River. Lake whitefish have been caught along Richards Island and the Tuktoyaktuk Peninsula. They have also been caught in small numbers in Phillips Bay, Yukon ranging in ages from 5 to 17, and no current-year spawners were recorded (Bond and Erickson 1987, 1989). Lake whitefish are not frequently caught in Liverpool Bay but 75% of those that are caught are between 390-459 mm in length (Bond and Erickson 1993). Adult lake whitefish, ages 7-10, use the Mayogiak and Freshwater lake systems as feeding areas. An upstream migration in these systems is seen immediately after ice out until mid-July, with the downstream migration peaking from late August to early October (Lawrence *et al.* 1984; Bond and Erickson

1985). In Wood Bay during August there is an increase in numbers of large whitefish along the coast indicating the start of the migration run back to the Anderson River to spawn. (Bond and Erickson 1992).

Lake whitefish have not been reported from saline waters, they have less of a salinity tolerance than most other coregonine species (Reist and Bond 1988). Anadromous lake whitefish grow slower and live shorter lives than lacustrine lake whitefish (Lawrence *et al.* 1984). Adult lake whitefish mature between age 7 and age 13 (Stein *et al.* 1973; Alt and Kogl 1973; Percy 1975; De Graaf and Machniak 1977; Bond 1982; Bond and Erickson 1991, 1992, 1993). Adults in the Chatanika River, Alaska mature at age 4 and 5 whereas in the Coville River, Alaska, lake whitefish mature at age 8 and 10 (Alt and Kogl 1973). The maximum age for lake whitefish has been reported between 20 to 34 years of age (De Graaf and Machniak 1977; Bond and Erickson 1991, 1992, 1993). Lake whitefish do not spawn every year, rather every second or third year (Scott and Crossman 1973; McCart *et al.* 1976).

Adfluvial

Adfluvial lake whitefish spawn in rivers in shallow running water or rapids over gravel and rubble with the young moving into lakes after hatching to develop (Machniak 1975a). Lake whitefish have been found in the delta of the Slave River and are thought to use this river for spawning. A spawning run upriver occurs between August and September into the upper areas of Slave River, with actual spawning occurring in late October in waters ranging in temperatures from six to a low of 0°C (McLeod 1985). Lake whitefish may also use the Great Bear River for spawning as mature adults have been caught in the river (McCart 1982). An upstream spawning migration into the Little Buffalo River began in August and ran until October, with fish being caught in the spawning area from the beginning of September to the beginning of October. The water temperature during this time was 6-10°C (Roberge *et al.* 1985). Spawning in the Peace River, AB occurred on a shallow shelf (0.6 to 1.0 m) covered with gravel, pebble and cobble substrates. Surface velocities ranged from 0.3 to 0.7 m/s (Patalas 1993). In the Athabasca River, AB substrates used for spawning ranged from rock and boulder to mixed gravel and sand. Spawning takes place during mid-September to late October, with water temperatures ranging from 6.5 to a low of 2.5°C. The most common substrate used was gravel, rubble and boulder (none were found on silt, sand or bedrock) and most common depth was 2.0-2.5 m, with a current of 1.0 m/s (McCart *et al.* 1982). Eggs were not found on pure sand or mud bottom (Jones *et al.* 1978a). In Swedish lakes the currents of spawning rivers are generally moderate to slow (Lindstrom 1970). In the Poplar River (Manitoba), lake whitefish began to spawn from the end of September to late October, in water temperatures from 9.4 to a low of 2.5°C (Green and Derksen 1987).

Once juveniles enter the lake they usually remain there to rear until they reach maturity and return to the river to spawn. In Swedish lakes the offspring may leave the spawning river as egg, alevins or later in the life cycle (Lindstrom 1970). Young-of-the-year have been observed near the surface in running water (total depth 0.25-0.5m), sometimes hiding behind boulders or small points (Lindstrom 1970). The ecology of adfluvial lake

whitefish in lakes is poorly understood and may be confused with that of co-occurring lacustrine life history types.

Adfluvial lake whitefish adults, after spawning in the Little Buffalo River, migrate downstream to overwinter and feed in Great Slave Lake. The oldest fish caught in Little Buffalo River was 13 and the youngest fish capable of spawning was five to eight years old (Roberge *et al.* 1985). They are also reported to occur in the Rivere La Martre system. Here the oldest fish caught was ten years old (Chang-Kue *et al.* 1987).

Broad whitefish (*Coregonus nasus* (Pallas 1776))

Broad whitefish are found along the northern coastal regions of the NT and NU as far east as Perry River, and inland in the Mackenzie River drainage basin upstream to Fort Smith (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980; Bond and Erickson 1992). They also are found in the Coppermine (Scott and Crossman 1973; Stewart and MacDonald 1978; Sutherland and Golke 1978; Stewart 1997), Hornaday (Sutherland and Golke 1978) and Anderson rivers (DFO 1999).
Typically they are found in larger, lower gradient and moderately turbid river systems, delta lakes and brackish estuaries as they are primarily an anadromous species (Scott and Crossman 1973). Within the NT this species exhibits both anadromous and lacustrine life history types (Berg 1962; Scott and Crossman 1973; Reist and Bond 1988; Reist and Chang-Kue 1997; Reist *et al.* In prep.). Broad whitefish may also exhibit a riverine life history type within the NT but this is not confirmed. Anadromous populations have been reported to spawn in the Mackenzie, Peel, and Arctic Red rivers as well as in the Travaillant Lake system (Stein *et al.* 1973; Reist and Bond 1988; Thera 1998). A freshwater resident form also exists in the Travaillant Lake system (Reist and Chang-Kue 1997) as well as in other lakes of the area, and has been described in Siberia (Berg 1962). The lacustrine form is treated in detail in Richardson *et al.* (2001). The degree of mixing of the two to perhaps three life history types during some stage of their life is not known but can occur because no physical barriers exist to fish movement between many of the lakes and rivers (Reist and Chang-Kue 1997).

Ecoregion - Adult anadromous broad whitefish spawn and overwinter in the Lower Mackenzie ecoregion, but feed mostly along the coast and in and among rivers and lakes of the North Arctic ecoregion. Young-of-the-year and juveniles spend nursery time feeding in rivers and lakes in the North Arctic ecoregion.

Anadromous populations in the NT and NU begin to move upstream in July and August (Wynne Edwards 1952) with the run peaking during September and October (Stein *et al.* 1973; Jessop and Lilley 1975). Spawning takes place under the ice in November over gravel areas in the rivers with the young hatching in spring (April-May). They are then carried downstream by the spring run-off (Morrow 1974; Jessop and Lilley 1975; Bond and Erickson 1985; Chang-Kue and Jessop 1992). Bogdanov *et al.* (1992) describe spawning in Russian rivers as taking place in shallows and pools with sandy-gravel and rocky substrates, with hatching occurring under the ice when current speed reaches 0.16

to 0.2 m/s. Eggs need 185-190 days for development and are swept downstream by currents greater than 0.4 m/s.

The young disperse along the coastal areas of the Beaufort Sea (Morrow 1974; Jessop and Lilley 1975; Bond and Erickson 1985; Chang-Kue and Jessop 1992). For example, in the Mackenzie River, the majority are carried through the delta and swept eastward along Tuktoyaktuk Peninsula. Some are carried out of the western channels of the delta and then eastward along Richards Island and a smaller proportion are carried further westward along the Yukon north slope (Bond and Erickson 1987; Reist and Chang-Kue 1997). As soon as the coastal rivers and creeks become ice free in late June and July the YOY begin upstream migrations to feeding and nursery areas (e.g., Freshwater Creek) (Bond and Erickson 1985; Reist and Chang-Kue 1997). Young-of-the-year migrations and feeding occur through the Mackenzie River, large tributary rivers originating from the mountains (e.g., Peel and Arctic Red rivers), channels of the inner delta (from Point Separation north to the tree line), channels, coastal lakes, and creeks of the outer delta (tree line northwards), and nearshore habitat, and lakes and creek systems along the Tuktoyaktuk Peninsula (Reist and Bond 1988; Reist and Chang-Kue 1997). Young-of-the-year overwintering areas include channel-connected lakes of the inner delta, coastal lakes of the outer delta, and lake and creek systems of Tuktoyaktuk Peninsula (Reist and Chang-Kue 1997). Juvenile migrations and feeding occur in the same habitat types as YOY fish. Upstream migrations of juvenile fish in Freshwater Creek and Kukjuktuk Creek are heaviest in late June and early July (Bond and Erickson 1985; Chang-Kue and Jessop 1992). The juveniles overwinter in coastal lakes (> 3m deep) and streams (e.g., Tuktoyaktuk Peninsula) and remain in these areas for 1-4 years before migrating to the coastal waters again (Jessop and Lilley 1975; Bond and Erickson 1985; Chang-Kue and Jessop 1991; Hesslein *et al.* 1991). Between ages 4-6 the juveniles make seasonal migrations from overwintering sites in the Mackenzie delta to feeding sites in the coastal areas (Bond and Erickson 1985). Young and juveniles caught in lakes are found associated with the following substrate types: sand, cobble, silt and gravel. Willows and grass are found along the lake shore lines but no association with catches of fish were summarized. There were a few instances when fish were caught near submerged vegetation, but again no direct associations were made (Bond and Erickson 1982).

Adults spend most of their lives in the brackish estuaries along the coastline where they feed (Morrow 1974; Hesslein *et al.* 1991). Broad whitefish in the Beaufort Sea region reach sexually maturity around 7-9 years of age (de Graaf and Machniak 1977; Bond 1982; Chang-Kue and Jessop 1992; Reist and Chang-Kue 1997). After spawning in November the adults move downstream to deeper parts of rivers, inner estuaries or coastal areas to overwinter (Morrow 1974; Bond and Erickson 1985; Chang-Kue and Jessop 1992). Older fish (8-13 years old) have been found to spend one or more years in lakes without migrating (Chang-Kue and Jessop 1991; Hesslein *et al.* 1991). Once mature broad whitefish do not necessarily spawn every year, but likely rest for one or more years (Bond and Erickson 1985).

Least cisco (*Coregonus sardinella* (Valenciennes 1848))

The least cisco is found in western North America and Siberia. In North America it occurs from Bristol Bay throughout Alaska, eastward along the Beaufort Sea coast to Bathurst Inlet and Cambridge Bay (McPhail and Lindsey 1970). It is common along coastal areas near the Mackenzie River delta, as far upstream as Fort Simpson in the NT, and on Victoria and Banks islands, then east to the Murchison River in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Babaluk *et al.* unpublished data). Least cisco can be found in freshwater streams, rivers and lakes as well as estuaries and coastal lagoons (McPhail and Lindsey 1970; Scott and Crossman 1973; Lawrence and Davies 1978). They exhibit both anadromous and freshwater lacustrine life history types (McPhail and Lindsey 1970; Scott and Crossman 1973; Mann 1974; Lee *et al.* 1980; Lawrence *et al.* 1984). Dwarf and normal-sized individuals are documented in lacustrine populations (Mann and McCart 1981), but anadromous populations consist of only one size type. Anadromous populations spawn in rivers (Stein *et al.* 1973; Morrow 1980) while lacustrine populations spawn in lakes (Mann 1974; Lawrence 1984). For more information on lacustrine habitat requirements for the least cisco refer to Richardson *et al.* (2001).

Ecoregion - The least cisco is found in the Upper Mackenzie, North Arctic, and Western Arctic Islands ecoregions.

Least cisco are less migratory than Arctic cisco and tend to be more closely associated with the brackish nearshore area close to their home stream (Craig 1984, Reist and Bond 1988). Younger, smaller least cisco tend to remain closer to their river of origin while the longest coastal migrations are undertaken by older, larger individuals (Bond and Erickson 1993).

The upstream migration of least cisco begins in the Mackenzie Delta in late August and continues through September, with spawning occuring in late September to early October (Stein *et al.* 1973). A major influx of cisco occurs by late August in the lower reaches of the Middle and East channels of the Mackenzie River (Percy 1975, Chang-Kue and Jessop 1992). Least cisco are believed to spawn in the Peel and Husky channels as well as the Arctic Red River (Stein *et al.* 1973). They spawn in areas of the rivers with sand or gravel substrates and scatter the eggs over the bottom (McPhail and Lindsey 1970; McCart and Den Beste 1979). In Alaska the least cisco spawns in late September to early October, at night, at depths of 1.3-2.6m, and velocities of 0.5 m/s. Surface water temperatures were between 0 to 3°C (Kepler 1973) and the stream bottom was composed of gravel with little sand. Eggs sink to the bottom and lodge in the crevices of the gravel (Kepler 1973).

Eggs hatch in May or June under the ice and the YOY move downstream to slower water (McPhail and Lindsey 1970; Mann 1974; Townsend and Kepler 1974). Young least cisco are dispersed down river by the spring run off in the Mackenzie River and are found in the Mackenzie Delta and near the river mouth (Percy 1975; Lawrence *et al.* 1984). Most YOY appear to remain in the delta and river mouth of the Mackenzie River (Percy 1975; Lawrence *et al.* 1984). Other YOY and juveniles may migrate along the coast during the summer months, east to Wood Bay, Liverpool Bay, Kugmallit Bay, Anderson River

estuary and other areas near Tuktoyaktuk Harbour and the Tuktoyaktuk Peninsula (Bond 1982; Hopky and Ratynski 1983; Bond and Erickson 1991, 1992, 1993). In the Anderson River estuary age 1 and 2 fish are abundant from the beginning of July to mid-July. Age 0 least cisco appear in the estuary in early August (Bond and Erickson 1991). Young-of-the-year became abundant in the Kugmallit Bay area during mid-July to the end of July as the young ciscoes disperse to rearing areas along the coast of the Tuktoyaktuk Peninsula (Bond 1982). Least cisco that likely originate from the Mackenzie River are also known to migrate west as far as Phillips Bay, Yukon, although their abundance decreases dramatically further from the delta. Juveniles also move inland into freshwater systems along the Tuktoyaktuk Peninsula to feed (Lawrence *et al.* 1984). They have been recorded in the mouths of Mayogiak and Freshwater creeks (Bond 1982). Juveniles using freshwater lake systems to feed enter those systems in July and leave in August/September, but many may also stay to overwinter in these areas (Bond and Erickson 1985; Chang-Kue and Jessop 1992). Overwintering also occurs in the Mackenzie Delta (Bond 1982).

Adult least cisco move back downstream after spawning to overwinter in the Mackenzie Delta. Adults do not spawn every year, but likely every two to three years (Mann 1974). During the summer months they spend their time along the coast migrating and feeding, similar to the patterns of the juveniles, but they may enter more saline environments and migrate larger distances. They are found in Liverpool Bay, Anderson River estuary, Wood Bay, Kugmallit Bay, Phillips Bay, in the freshwater systems of Freshwater and Kujuktuk creeks and in other areas of the Tuktoyaktuk Peninsula (Galbraith and Hunter 1975; Jessop and Lilley 1975; Percy 1975; Steigenberger *et al.* 1975; Bond 1982; Hopky and Ratynski 1983; Bond and Erickson 1982, 1987, 1989, 1991, 1993). These areas also serve as overwintering areas (Percy 1975; Galbraith and Hunter 1975; Steigenberger *et al.* 1975). Individual stocks of least cisco are thought to occur within the Mackenzie River, Anderson River, and perhaps the Miner and Kugaluk rivers (Reist *et al.* unpublished 2002).

The oldest recorded least cisco, 28 years old, was caught in the Anderson River estuary (Bond and Erickson 1991). Other maximum ages reported ranged from 11-26 (Scott and Crossman 1973; Bond and Erickson 1987, 1991, 1993). Adults mature between ages 5-16 for males and ages 5-13 for females (Hartfield *et al.* 1972; Bond and Erickson 1991, 1993).

Pink salmon (*Oncorhynchus gorbuscha* (Walbaum 1792))

North American Pacific salmon species occur in small numbers in Arctic waters. Along with chum salmon, pink salmon are not very abundant in the Canadian portion of the Beaufort Sea. In the NT pink salmon have been reported in the Mackenzie River system as well as in the Sachs River estuary of Banks Island, but they have not been reported to occur in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Hunter 1974; Lee *et al.* 1980; Babaluk *et al.* 2000b). Pink salmon are strictly anadromous and are not known to show any type of freshwater resident life history type in the NT (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). They spawn in rivers and only ascend

short distances up rivers (300 km) compared to the chum salmon which may ascend over 2000 km (McPhail and Lindsey 1970; Morrow 1980; Craig and Haldorson 1986; Heard 1991).

Ecoregion – Pink salmon occur in the Lower Mackenzie and Western Arctic Island ecoregions.

Although pink salmon have been caught in the Mackenzie River and the Beaufort Sea area they are not known to spawn in the NT (Craig and Haldorson 1986).The following life history and habitat description is for pink salmon occurring in Alaskan waters, as well as in Russia. Pink salmon adults ascend the rivers from mid-June to late September (Neave *et al.* 1967) and spawning takes place during August and September over clean walnut-sized gravel in water approximately 30 cm deep in areas of riffles (Hunter 1959; McPhail and Lindsey 1970; Morrow 1980; Heard 1991). Spawning beds in Russian rivers consisted of coarse gravel with a few large cobbles, a large mixture of sand, and a small amount of silt (Dvinin 1952; Smirnov 1975). In southeastern Alaska spawning beds were composed of 14.3 percent sand, 31.4 percent gravel and 54.1 percent cobble (McNeil and Ahnell 1964). They avoid spawning in areas of quiet deep water, in pools, in areas of slow current, or over heavily silted or mud-covered streambeds (Heard 1991).

The female digs a redd in a riffle area, or occasionally just below a pool area. After spawning the female covers the eggs (McPhail and Lindsey 1970; Morrow 1980). Both parents die after they finish spawning (i.e., semelparous life history) (McPhail and Lindsey 1970; Morrow 1980; Heard 1991). They can spawn at depths between 30-100 cm, but mainly at depths of 20-25 cm (Dvinin 1952; Hourston and MacKinnon 1956; Vasilenko-Lukina 1962; Eniutina 1972; Graybill 1979; Golovanov 1982). Currents ranged from 0.3 to 1.4 m/s (Dvinin 1952; Soin 1954; Hourston and MacKinnon 1956; Vasilenko-Lukina 1962; Kobayashi 1968; Smirnov 1975; Graybill 1979; Golovanov 1982).

Development of the eggs takes 61-130 days depending on incubation temperature (Bailey and Evans 1971). Hatching of the eggs occurs from December to February (Scott and Crossman 1973). The alevins remain in the gravel until April or May when they emerge and move immediately downstream, migrating at night and hiding in the gravel during the day (Neave 1955; McPhail and Lindsey 1970; Morrow 1980). They remain in coastal areas for several months and then venture out to sea to feed and mature (McPhail and Lindsey 1970).

Pink salmon only have a two year life span, rarely are three year-old fish found (Anas 1959; Turner and Bilton 1968; McPhail and Lindsey 1970). After spending 18 months at sea adult pink salmon return to their natal stream to spawn, but on occasion wander into a different stream to spawn (Scott and Crossman 1973; Morrow 1980). Since the fish only live for two years they have a distinct even-year and odd-year spawning runs. In western, central and southeastern Alaska there are more pink salmon in even-numbered, than in odd-numbered years (Heard 1991).

Chum salmon (*Oncorhynchus keta* (Walbaum 1972))

In the NT chum salmon are found along coastal regions, in the Peel and Mackenzie rivers and possibly as far east as the Anderson River. Within the Mackenzie River drainage they have been found in the Slave River below Fort Smith, in the mouth of Hay River and into Great Bear Lake (Dymond 1940; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Salo 1991). Chum salmon spend very little time in freshwater, they only enter freshwater to spawn during the course of their life history. They use rivers and lakes as migration routes to spawning areas which occur strictly in riverine environments (McPhail and Lindsey 1970). Chum salmon are strictly anadromous, no freshwater resident populations are known to exist (McPail and Lindsey 1970; Scott and Crossman 1973; Salo 1991).

Ecoregion – Chum salmon are found in the Lower Mackenzie River and North Arctic ecoregions.

The chum salmon is a fall spawner, spawning during the months of September and October (Morrow 1980). There has also been documentation of two separate spawning runs occurring in rivers in Alaska and Siberia, one during the summer in which fish are generally smaller (weigh less) and one during the fall in which the fish are larger (Nikolskii 1961, Morrow 1980). Spawning in the lower Colville River, Alaska, occurs from mid-August to mid-September (Bendock 1979). Two spawning migrations of anadromous chum salmon from the Beaufort Sea are known – upper Liard River in northern British Columbia during September (McLeod and O'Neil 1983), and at the rapids at Fort Smith, NT on the Slave River in late September to November (McPhail and Lindsey 1970; Scott and Crossman 1973; McLeod 1985). In the Liard River chum salmon first appeared on the spawning grounds in early October and were present through to November when sampling ceased (O'Neil *et al.* 1982).

In Alaskan rivers the first spawning chum salmon are seen in the rivers during May to July (Morrow 1980; Salo 1991). The salmon spawn in spring or ground-water fed streams in turbulent areas or where upwellings occur (Morrow 1980; Salo 1991). Spawning occurs over gravel (2-3 cm) but areas of coarser stone, or bedrock covered in boulders, have also been used (Scott and Crossman 1973; Morrow 1980). The female constructs a large pit (20-40 cm deep), deposits her eggs which are fertilized by the male, and then covers the pit by constructing another pit upstream (Scott and Crossman 1973; Morrow 1980; Salo 1991). Both males and females die after spawning (i.e., they exhibit a semelparous life history) (Morrow 1980).

In Washington state, chum salmon spawned in velocities of 0.0 to 1.67 m/s (80% between 0.21 to 0.83 m/s) and the water depth over the redds ranged from 13.4 to 49.7 cm (Johnson *et al.* 1971). In Japan chum salmon chose water velocities of 0.1 to 1.0 m/s, at water depths ranging from 20-110 cm (Sano and Nagasawa 1958; Soin 1954). Eggs require 122-173 days to hatch, depending on the environment in which they are incubating (Salo 1991).

Hatching occurs under the ice, and the alevins remain in the gravel bed until the yolk sac is absorbed between 60-90 days after hatching, after which they rise from the gravel and begin to migrate to the sea (Nikolskii 1961). This migration occurs over the evening hours during summer, with the YOY hiding in the stream bottom during the day (Neave 1955, Hoar 1956, Meehan and Siniff 1962). While migrating fry are attracted to the shade and darkness provided by waterweed communities (Salo 1991). Once they reach the sea the young remain close to shore for the first few months, and then disperse farther out to the open ocean (Morrow 1980). The young remain in the open ocean for three to five years feeding and maturing. Once the adults mature they return to their natal stream to spawn (Salo and Noble 1952). Adults mature at ages two to six, with 95% mature between the ages of three and five (Salo 1991).

Kokanee or Sockeye salmon (*Oncorhynchus nerka* (Walbaum 1792))

Oncorhynchus nerka is distributed in the north Pacific Ocean and occurs in two forms: sockeye salmon exhibits an anadromous life history, while kokanee are derived from anadromous populations, do not migrate to sea, and remain as freshwater residents for their entire life (Nelson 1968; Burgner 1991).

Sockeye occur in North America along coastal regions from California, north to Point Hope, Alaska. They are also present in northeast Asia from northern Hokkaido north to the Anadyr River (McPhail and Lindsey 1970; Morrow 1980). Sockeye are abundant in the Bristol Bay area of Alaska and become increasingly rare as you travel north (McPhail and Lindsey 1970). Stragglers have been reported in Bathurst Inlet, NU (Hart 1973; Hunter 1969; Morrow 1980); from the Mackenzie and Arctic Red rivers, NT (Dymond 1940; Wynne-Edwards 1952; McPhail and Lindsey 1970; Hatfield *et al.* 1972; Hart 1973; Scott and Crossman 1973; Stein *et al.* 1973; Morrow 1980; O' Neill *et al.* 1982; Craig and Haldorson 1986; Babaluk *et al.* 2000a); from Holman Island, NT (Hunter 1974); and from Sachs Harbour, NT (Babaluk *et al.* 2000a). They are not known to spawn in the NT or NU.

Kokanee are indigenous to lakes of the Pacific Ocean drainage in North America and northern Asia. They occur in Alaska, Yukon, British Columbia, Washington, Idaho, and Oregon (Nelson 1968; Burgner 1991). There is a population of kokanee in Arctic and Thutade lakes in the headwaters of the Peace River, B.C. (Mackenzie River system) (Nelson 1968; McPhail and Lindsey 1970). Kokanee have also been reported from Great Slave Lake, NT (Babaluk *et al.* 2000b). They are not known to spawn in the NT or NU.

Since there are no permanent populations of sockeye or kokanee salmon in the NT or NU all information below is from populations occurring in other areas and general summary of habitat and life history is given.

Ecoregions – Sockeye are very rarely found in the Lower Mackenzie and North Arctic ecoregions.

Anadromous (Sockeye)

Sockeye salmon ascend natal rivers and streams in Bristol Bay in early June to August, with spawning occurring from August to September. Most spawning occurs in rivers that connect to lakes, but some fish do spawn along the lake shoreline where ground water upwelling occurs. Redds are constructed by the females in gravel substrates in areas where riffles occur and after the spawning act the female will cover up the eggs with gravel by constructing a new redd upstream. Both adults die after spawning (McPhail and Lindsey 1970; Morrow 1980; Burgner 1991). Spawning substrate consists of areas of fine gravel, but may be over large cobble or even among large rocks (Ricker 1966). Preferred sites have <10% cobble, ~90% gravel (Hoopes 1962, 1972). There does not seem to be a preferred depth of water for spawning. It can occur in rivers in only 10 cm of water or along the shorelines of lakes were depths reach 30m or more (Burgner 1991).

Sockeye salmon eggs hatch after 6-9 weeks of incubation, but may require up to five months depending on the temperature of the water (Hart 1973; McPhail and Lindsey 1970). The alevins remain in the gravel for 2-3 more weeks living on their yolk sacs and emerge sometime in April to June. The fry then either remain in their natal stream or move from the stream into the nearby lake, moving downstream or upstream (McPhail and Lindsey 1970; Morrow 1980; Burgner 1991). If they remain in the stream instead of migrating to the lake, they spend the day hiding in the stones and gravel bed of the stream only emerging at night (Morrow 1980). They remain in freshwater environments for one to two years until smolting and migrating to the sea after ice breakup occurs. They remain in the sea for two to four years (McPhail and Lindsey 1970; Morrow 1980) and once mature return to their natal stream to spawn.

Freshwater Resident (Kokanee)

Spawning occurs in rivers or lakes in similar habitats and similar times as described for sockeye (Morrow 1980). The anadromous marine phase is omitted, and instead both the juveniles and adults remain in the lake feeding and maturing (Kimsey 1951). Adults mature age ages 3-5 and are much smaller than anadromous sockeye (McPhail and Lindsey 1970). As with sockeye, kokanee adults die after spawning.

Chinook salmon (*Oncorhynchus tshawytscha* (Walbaum 1792))

In North America spawning populations of chinook salmon are found from southern California to Point Hope, Alaska. They also occur in northeastern Asia from northern Hokkaido north to the Anadyr River (Shmidt 1950; McPhail and Lindsey 1970; Healy 1991). Chinook salmon have been consistently reported from Point Barrow, Alaska and the Mackenzie Delta region of NT (Dymond 1940; McPhail and Lindsey 1970; Morrow 1980). Strays have been reported from the Coppermine River, NU (Hunter 1974; Morrow 1980) and in the Liard River, NT near Fort Smith (McLeod and O'Neil 1983). Chinook salmon are strictly anadromous, and only enter freshwater rivers to spawn (McPhail and Lindsey 1970; Morrow 1980; Healy 1991). There are no known spawning populations in the NT or NU. Thus only a brief habitat and life history account are given.

Ecoregion – A few occurrences of chinook salmon have been reported in the Lower Mackenzie and North Arctic ecoregions.

Chinook salmon begin to ascend rivers to spawn in late May and early June, and they may travel over 2000 km to reach their spawning grounds. Spawning occurs in late July to early September in the upper Yukon River (McPhail and Lindsey 1970; Scott and Crossman 1973; Morrow 1980; Healy 1991). Chinook salmon spawn in larger streams and choose areas with coarser gravel and deeper water than other Pacific salmon. Chinook salmon spawn in water with a depth of a few centimeters to a few meters, and velocity from 0.1 to 0.52 m/s to a maximum of 0.64 to 1.50 m/s. Substrates used for spawning vary from fine gravel, to coarser gravel and cobble (Healy 1991). Subgravel flow of water seems to be the defining characteristic for redd location (Healy 1991). The female chooses a riffle area of a river and digs a redd in the substrate, spawning occurs, and then the female moves upstream and begins to dig another redd, in the process covering her eggs downstream. After they have completed spawning the adults die (i.e., they are semelparous) (McPhail and Lindsey 1970; Morrow 1980).

The eggs hatch in about seven to nine weeks depending on water temperature, but can take as long as 159 days. The young remain in the gravel substrate after hatching and emerge after two to three weeks. In the Yukon River the young remain in freshwater for two years before smolting and moving downstream to the sea (McPhail and Lindsey 1970; Morrow 1980; Healy 1991). While rearing in freshwater (Big Qualicum River, BC) small chinook are found in marginal areas of rivers, particularly back eddies, behind fallen trees, undercut tree roots or other areas of bank cover. When they grow larger they move out into the middle of the stream where water velocity is higher (Lister and Genoe 1970). In the Snake River, OR juvenile chinook were most abundant where substrate particle size was small, velocity low, and depth was shallow. When fish moved offshore into stronger currents they were found over boulder and rubble substrate (Chapman and Bjornn 1969; Everest and Chapman 1972). Young fish do well in cold, clear streams and do not venture into lakes at all (Higley and Bond 1973). When it is time to begin migrating to the sea the fish smolt, losing their parr marks, and spend more time in deeper water and avoid light. The migration downstream occurs mostly at night (Morrow 1980).

Once they reach the sea they remain nearshore for a time before seeking deeper waters (Morrow 1980). Females remain at sea four to five years and return to spawn when they are six to seven years of age. Males mature earlier and only spend two to three years at sea (McPhail and Lindsey 1970).

Round whitefish (*Prosopium cylindraceum* (Pallas 1784))

The round whitefish is found in the NT and NU from Great Slave Lake throughout the Mackenzie River valley in the NT, eastward through to the Keewatin district of NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980). It is usually common in shallows of lakes, ponds, slow-flowing rivers and streams, as well as in brackish waters (McPhail and Lindsey 1970; Scott and Crossman 1973). It

shows lacustrine, adfluvial and possibly riverine life history types (Normandeau 1969; Bryan and Kato 1975; Goodyear *et al.* 1982; Morin *et al.* 1982). Spawning occurs mainly in lakes but on occasion round whitefish spawn in rivers and clear streams (Normandeau 1969; McPhail and Lindsey 1970; Scott and Crossman 1973; Bryan and Kato 1975; Morrow 1980; Becker 1983; Haymes and Kolenosky 1984). For information concerning lacustrine life history and habitat requirements please see Richardson *et al.* (2001). Although common in northern waters in Canada the round whitefish is one of the least studied coregonines (McPhail and Lindsey 1970; McKay and Power 1968).

Ecoregion – They are found in the Lower Mackenzie, Upper Mackenzie, North Arctic, and East Arctic ecoregions.

The upstream migration of round whitefish occurs in late October and spawning occurs over gravel with no nest built (McPhail and Lindsey 1970). Typically spawning takes place at temperatures slightly above 0°C (Morrow 1980). In the East Arctic ecoregion round whitefish spawn in late fall (October) in areas of rivers with gravel and rubble substrate, free of sand and silt at temperatures of 4.5°C and in water less than 9 m deep (Lawrence *et al.* 1978). In the Yukon (Aishihik Lake and East Aishihik River) round whitefish spawn in November during the day. Eggs were broadcast over silt, *Potamogeton*, gravel, and boulder. Spawning occurred in both fast and slow water, at depths ranging from 70 to 250 cm. The most widely used spawning area was in fast current at depths less than one meter. Water temperatures at the time of spawning is 0.8 to 2.2°C (Bryan and Kato 1974). Round whitefish use the Susitna River, Alaska, to spawn in slow to moderate water velocities with silt to rubble substrate during October to November and may seek areas with adequate ground water upwelling. (Sundet and Wenger *et al.* 1984). Round whitefish spawned in the mainstem Susitna River or in tributary mouths in substrates composed of cobble, rubble, gravel, silt and sometimes boulder, at a water depth of 51.8 to 128 cm and at temperatures close to 0°C (Suchanek *et al.* 1984). There is no parental care given to the eggs or the offspring.

Eggs overwinter under the ice and hatch in April and May after 123-140 days of incubation (Scott and Crossman 1973; McKinley 1983; Walker 1983). After hatching the larvae preferred sand substrates when given a choice between sand, cobble and gravel (McKinley 1983). In the Chena River, Alaska, round whitefish larvae are found in backwater areas and shallow shoreline areas where water velocity is either zero or slight and substrate consists of sand or mud. The larvae position themselves 5 to 20 mm from the substrate. Where vegetative cover is present it is not utilized (Lee 1985). In the Anadyr River (eastern Chukotka, Siberia) round whitefish larvae are first caught in mid to late May a few days before ice break up, and the last larvae were seen in June as they moved downstream. The water temperature during the migration was between 0-5.8°C with the abundance of larvae directly related to the discharge of the river (Shestakov 1991). Juveniles in the Susitna River, Alaska, will migrate to the lower river for rearing during their first year (Sundet and Wenger 1984). Young round whitefish use high turbicity water for cover. They also use objects for cover in the form of cobble or boulders, debris, and overhanging riparian vegetation evenly at water depths of 5-15 cm (optimal) to a maximum depth of 3 m, and prefer calm areas of water (Suchanek *et al.*

1984). Juvenile round whitefish, in the Chena River, are found in waters with temperatures ranging from 6 to 17°C. The use of logs, debris, or vegetation for cover was not observed, but they were found in the highest densities over silt substrates (i.e., use rubble, gravel and sand very sparingly) with a water velocity of 0.2 m/s, and depths of 30-45 cm and 0-15 cm. As fish grow they tend to move into deeper and faster water (Lee 1985).

When found in rivers adult round whitefish prefer areas that are turbid when no other cover is available. They utilize the following cover types (preferred to least preferred): cobble and boulder, undercut banks, overhanging vegetation, debris/deadfall, submergent vegetation, emergent vegetation, rubble and large gravel. Optimal water velocities ranged from 0.61 to 0.91 m/s (Suchanek *et al.* 1984). In northern Alaska round whitefish adults preferred deep pools in large streams with relatively low velocities (0.17 m/s), coarse substrates and are found near undercut banks half the time (DenBeste and McCart 1984). In the Susitna River, Alaska, and the Koksoak and George rivers, PQ, the oldest fish caught was 12 years of age (Sundet and Wenger 1984; MacKay and Power 1968). Most round whitefish mature at age 6-9 (Kennedy 1947, 1949). However males in northern Quebec mature between ages 4-7 while females mature from three to six years of age (MacKay and Power 1968).

Mountain whitefish (*Prosopium williamsoni* (Girard 1856))

The mountain whitefish is only found in northwestern North America from the interior drainage of Nevada and the upper Colorado systems, north to the Stikine, Liard and Mackenzie rivers. In Canada it is known from the Mackenzie River headwaters, in the upper Liard River downstream as far as Peace River. It is also found in the Athabasca River, AB downstream to the Athabasca townsite. In the NT it is also found downstream in the mainstream and tributaries of the Mackenzie River, to Mountain River and it has not been found in the NU (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Dryden *et al.* 1973; Scott and Crossman 1973; Stein *et al.* 1973; Jessop *et al.* 1974). Mountain whitefish can be found in lakes and streams that are either clear or silty (McPhail and Lindsey 1970). There are lacustrine, adfluvial and riverine life history types (McPhail and Lindsey 1970; Mann 1976; Swanson *et al.* 1994; Brown 1952). Richardson *et al.* (2001) does not describe the lacustrine habitat requirements, as they are rarely found in lakes in the NT.

Riverine

Spawning takes place from September to February (Brown 1952; McPhail and Lindsey 1970; Pettit and Wallace 1975; Mann 1976; Thompson and Davies 1976; Swanson *et al.* 1994; Ford *et al.* 1995; Wydoski 2001). Eggs are broadcast over gravel in riffle areas of streams and no nests are built (McPhail and Lindsey 1970; Ford *et al.* 1995). In the Flathead River, Montana, spawning takes place in water temperatures of 3-4°C, in pool areas directly below riffle areas, of the river in water 2-4 m deep (Mann 1976). In northern Alberta mountain whitefish spawn in areas where there are riffle waters, clean cobble bottom, with some pebbles and boulders and no vegetative channel cover

(Swanson *et al.* 1994). Spawning in Sheep River, Alberta occurs in shallow, fast, midstream areas, temperatures ranged from 0 to 8°C, water velocities averaged 1.02 m/s with a range of 0.63 to 1.54 m/s, the average depth was 38.1 cm and ranged from 30.5 to 43.7 cm. On another spawning site the water velocity averaged 0.90 m/s and an average depth of 48.3 cm with a range of 40.6 to 63.5 cm. Spawning substrates were composed of cobble and boulder with some gravel, but no substrates were smaller than 5 cm. Eggs incubated a total of 180 to 210 days at 0°C (Thompson and Davies 1976). In Montana rivers there is no marked spawning migration, spawning takes place in gravel and rubble riffle areas of streams, in water depths from 12.7 cm to 122 cm (Brown 1952). In general mountain whitefish spawn in riffle sections of streams at depths of 0.1 to 1.0m, over gravel and cobble, at velocities of 0.89 to 1.02 m/s (Ford *et al.* 1995).

Eggs hatch in early spring (March - May) and fry are found along the edges of the stream and in backwaters for several weeks after hatching (Brown 1952; McPhail and Lindsey 1970; Mann 1976). In Alberta eggs incubated for 36 to 127 days hatching in February to March (Ford *et al.* 1995). In an artificial environment kept at 6°C, mountain whitefish eggs hatched after 74 days of incubation (Rajagopal 1979). Rearing habitat consists of undercut banks and backwater or pool areas, with cobble, rubble and gravel covered in silt, and no vegetative cover (Swanson *et al.* 1994). Fry were found in water of 5-15 cm, in small well-protected pockets created by rubble and boulders (Brown 1952). Young, at the age of seven months have been seen schooling in Alberta rivers. Schools occupied bays of the river over mud bottoms (Nelson 1965). Juveniles prefer slow to moderate water velocity, depths of less than 3.0 m, sand and gravel substrates, cover ranging from cutbanks, woody debris, and aquatic vegetation (Ford 1995) and appear to prefer pool areas of a river system (Mann 1976).

Sexual maturity is reached at two-five years of age (McPhail and Lindsey 1970; Mann 1976; Thopmson and Davies 1976; Ford *et al.* 1995; Wydoski 2001). Adult mountain whitefish prefer depths less than 3 m in rivers and streams, and can be found in moderate to fast velocity water over cobble and gravel substrate, using cover of cutbanks, woody debris and aquatic vegetation (Ford *et al.* 1995). Adults can also be found in pool areas of rivers (Mann 1976) and use these areas to overwinter in (Swanson *et al.* 1994). Maximum age of mountain whitefish in the Flathead and Clearwater rivers was 14 years (Pettit and Walace 1975; Mann 1976).

Adfluvial

Adfluvial populations utilize the same river habitat for spawning as do riverine populations. After hatching the YOY move down stream to the lake or reservoir, and remain there until they are mature (Nelson 1965) then return into the river to spawn once they are sexually mature.

Arctic char (*Salvelinus alpinus* (Linnaeus 1758))

The Arctic char is the most northerly distributed freshwater fish occurring on northern Ellesmere Island, as well on many of the Arctic islands including Banks, Victoria, Devon, Somerset and Baffin (Walters 1955; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Babaluk *et al.* 1997). In coastal regions of the NT and NU Arctic char are found east of the Mackenzie River, around Boothia and Melville peninsulas and south along the west Husdon Bay coast. Only a few isolated populations (landlocked) occur west of the Mackenzie estuary (Reist *et al.* 1997). In some northern fresh waters it is the only fish present (Johnson 1980). They exhibit both anadromous and freshwater-resident lacustrine life history types (Scott and Crossman 1973; Lee *et al.* 1980; Johnson 1980; 1989) and may be found in rivers, lakes, esturaries and marine environments throughout their life cycle (Sprules 1952; McPhail and Lindsey 1970; Scott and Crossman 1973; Johnson 1989). Anadromous Arctic char spawn in rivers and/or lakes but in the north they seem to spawn exclusively in lakes that are deep enough to withstand freezing over winter as most rivers freeze completely (Balon 1980; Johnson 1980; Dempson and Green 1985; Cunjak *et al.* 1986). They make minimal use of rivers, mainly as migration routes, although some populations appear to spawn in larger rivers (Reist unpublished Kristofferson 1988; Macdonell 1996, 1997). For information on lacustrine habitat requirements and life history refer to Richardson *et al.* (2001).

Ecoregion - Arctic char are found in the North Arctic, East Arctic, Western Arctic Islands, and Eastern Arctic Islands ecoregions.

Anadromous Arctic char spawn on rock and gravel substrates located in lakes and streams during the fall (September and October). Eggs are deposited in shallow pools below rapids in the river on gravel beds (Sprules 1952; McPhail and Lindsey 1970; Scott and Crossman 1973; Stewart and MacDonald 1981). Spawning in rivers has been recorded in the Hornaday River, NT and is thought to occur in deep areas of the river and in areas close to La Ronciere Falls (Kristofferson 1988; MacDonell 1996, 1997). In the Cumberland Sound area of Baffin Island Arctic char constructed redds in the first week of September in water 0.5°C, 1-11 m deep, and with a current velocity of 0.2-0.7 m/s. Substrates varied from coarse sand to boulder-strewn gravel (Moore 1975a). Dempson and Green (1985) reported that spawning occurred in a section of the Fraser River (Northern Labrador) immediately downstream from a small lake. Redds were concentrated in areas of water 0.5-1.5 m deep. Substrates varied from fine and coarse sand to walnut-sized gravel. Char were also seen over areas of cobble and rubble but redds were not constructed in this area. Spawning occurred in October with water temperatures ranging from 1-3°C. In the Koroc River, northern Quebec (Ungava Bay),

redds were found in the river in shallow water on heterogeneous substrates (1-15 cm dia.) (a mix of sand, gravel and boulder) where surface water velocities were moderately strong (0.22 to 0.48 m/s), with water temperatures ranging from 3.7 to 8.3°C (Cunjak *et al.* 1986).

Females construct nests in the substrate and the covering of eggs after spawning is minimal as most eggs are in the first 5 cm of the substrate. Some females construct their nests in areas of groundwater upwelling (Cunjak *et al.* 1986). Due to energy restraints anadromous Arctic char can not spawn every year, likely every two to four years (Sprules 1952; Grainger 1953; Gyselman 1984a; Dutil 1986). Anadromous Arctic char have a high fidelity rate to their natal systems to spawn, but as they reach higher ages they are less likely to return to their natal stream. There is some exchange of fish between freshwater systems (Jensen and Berg 1977; Johnson 1980; Gyselman 1994), but this may be primarily by resting (i.e., non-spawning adults) or juvenile fish.

Eggs hatch in the spring (April) but the young fish remain in the gravel and continue to develop until they emerge as free swimming fry in July when planktonic food normally becomes abundant. Young char may invade small tributary streams where they feed on plankton and insects (Hunter 1976). Rearing areas of the Hornaday River are not known, but are most likely located in the lower reaches of tributary streams and along the shallows of the main river channel (MacDonell 1996, 1997; DFO 1999). Young-of-the-year have occasionally been observed in rivers, instead of along the shorelines of lakes, the young remained within 3 m of the shoreline, congregated in schools, and in water less than 1 m deep (Moore 1975a). In aquarium situations, after they absorbed the yolk sac, they remained close to the bottom of the tank, resting on the bottom or hiding under stones (Fabricius 1953; Fabricius and Gustafson 1954). In Norwegian streams most Arctic char juveniles are caught within 1-2 meters of the stream bank and in 0-30 cm of water with water velocities of 0-0.2 m/s. Juvenile char prefer slow velocities and spend time in pools (Heggberget 1984). Juveniles will remain in freshwater for a few years (3-8) and then undergo their first migration to sea (Sprules 1952; Grainger 1953; Moore 1975a; Hunter 1976; Dahlke and Falk 1979; Johnson 1980; Gillman and Kristofferson 1984; Dempson and Green 1985; McGowan 1987; Johnson 1989; McGowan 1992; Babaluk *et al.* 1998).

After smolting Arctic char make yearly migrations to the sea (McPhail and Lindsey 1970; Scott and Crossman 1973; Johnson 1980), except they may remain in freshwater prior to the fall that they spawn (Johnson 1989). The seaward migration occurs throughout the day and night as soon as spring ice breakup occurs between May and July (Moore 1975b; Dempson and Green 1985; Stewart and Bernier 1988; Johnson 1989). It consists of first-time migrants and repeat migrants, with the larger char leaving the freshwater system first. First-time migrants could have spent 1-8 years in freshwater before leaving, while repeats are adults that are spawners-of-the-year or resting fish (Dempson and Kistofferson 1987). During the spring and summer the Arctic char move along the coastal areas (distances of 40-50 km) feeding and exploring other freshwater rivers briefly. The older the fish the farther it travels away from its natal stream (Moore 1975b). While anadromous Arctic char are at sea they can migrate great distances over 180 km in one

summer (Gyselman 1994) but most char during a tagging study were caught within 70 km of the area in which they were tagged (Dempson and Kristofferson 1987). Arctic char are not known to overwinter at sea (Grainger 1953). They remain along the coastal areas feeding for the summer and return upstream during July, August and into early September with older fish migrating earlier than younger fish (Sprules 1952; Grainger 1953; Moore 1975b; Dempson and Green 1985; Dempson and Kistofferson 1987; McGowan 1987; Stewart and Bernier 1988; Johnson 1989; Lemieux and Kristofferson 1990; McGowan 1992). During the upstream migration char passed through riffle areas where the water is 10-15 cm in depth and ascended rapids with a water velocity of 2.5 to 3.0 m/s and overcame a waterfalls 1.5 m high but were stopped by a 3.3 m high waterfall (Moore 1975b). Arctic char are known to overwinter in deep holes of the Hornaday River and at the base of La Ronciere Falls (Kristofferson 1988; MacDonell 1996, 1997).

The oldest Arctic char recorded migrating ranged from 14-33 years (Sprules 1952; Grainger 1953; Hunter 1976; Sekerak *et al.* 1976; Dahlke and Falk 1979; Johnson 1980; Kristofferson and McGowan 1981; Kristofferson *et al.* 1982; Dempson and Green 1985; Stewart and Bernier 1988; Johnson 1989; McGowan *et al.* 1993). Sexual maturity is reached between ages 3-13 (Sekerak *et al.* 1976; Dahlke and Falk 1979; Dempson and Green 1985; Johnson 1989; Stewart and MacDonald 1981; Gillman and Kristofferson 1984; McGowan 1985; McGowan 1987; Stewart and Bernier 1988; Lemieux and Kristofferson 1990; McGowan *et al.* 1993).

Lacustrine char tend to exhibit high diversity manifested as anadromous vs. resident size variants (e.g., large vs. small), ecological and morphological variants, etc. with the latter two types restricted to lakes. It is unknown whether such variation is also exhibited by riverine forms. Some of these lacustrine variants have in the past been assumed to represent anadromous forms. For example, the large form of Arctic char present in Lake Hazen on Ellesmere Island (Reist *et al.* 1995), was originally thought to be anadromous, but now it is thought that they only make brief forays into the upper reaches of Ruggles River, and there is no evidence that they use the river as a passageway to the sea (Babaluk *et al.* 1997, 2001). The morphological differences seen between large and small forms in the lake are due to food segregation (Guiguer *et al.* 2002).

Bull trout (*Salvelinus confluentus* (Suckley 1859))

There has been much taxonomic confusion between bull trout and Dolly Varden identification and distribution in the past. Recent work has confirmed the presence of bull trout from several locations in the Mackenzie River valley extending its known range northward by approximately four degrees of latitude into the Redstone and Keele rivers and as far north as Great Bear River (Reist *et al.* 2002; Mochnacz unpublished data). Bull trout were previously thought only to exist as far north as Prairie Creek, NT (Haas and McPhail 1991). They are not known to exist in NU.

Bull trout are often found in rivers and streams although they can be found in lakes in association with spawning streams and rivers (Haas and McPhail 1991; Nelson and Paetz 1992; Ford *et al.* 1995; Boag and Hvenegaard 1997). They are also more likely to occur

in streams with high elevations (Paul and Post 2001). Bull trout exhibit riverine, stream-resident, anadromous and adfluvial life history types (Ford *et al.* 1995; Stelfox and Egan 1995; Baxter and McPhail 1996; James and Sexauer 1997; Wilhelm *et al.* 1999). Bull trout require clear stream channels and healthy riparian zones for rearing and spawning to occur and maintain healthy population numbers (N. Mochnacz, Natural Resources Institute, University of Manitoba, personal communication 2002). Bull trout have shown natural hybridization with Dolly Varden in the wild (Baxter *et al.* 1997). Much of the habitat information known about the bull trout is from southern areas of its distribution, little is known about bull trout habitats in the northern areas of its range (Reist *et al.* 2001), thus some modifications of the timing of life history events may be necessary in the NT. For information concerning the lacustrine life history requirements of the bull trout refer to Richardson *et al.* (2001).

Ecoregion – The bull trout is only found in the Lower Mackenzie ecoregion in the Liard and Mackenzie River system (Reist *et al.* 2001; N. Mochnacz, Natural Resources Institute, University of Manitoba personal communication 2002).

Regardless of life history type all bull trout spawn in smaller, cold streams and rivers (Fraley and Shepard 1989; Goetz 1989; Pratt 1992; Baxter 1997; Herman 1997; Rieser *et al.* 1997; Wissmar and Craig 1997; N. Mochnacz, personal communication). Spawning streams have the following characteristics: low gradients, small gravel substrate, proximity to cover, and low water velocity (Fraley and Shepard 1989). In larger streams and rivers, spawning redds are found in areas of groundwater upwelling (Baxter and McPhail 1996; Boag and Hvenegaard 1997; James and Sexauer 1997; Baxter and McPhail 1999). Bull trout select spawning reaches of streams with hyporheic groundwater discharge. These areas possess relatively stable thermal and flow regimes which may be important for egg incubation, emergence success and juvenile survival (James and Sexauer 1997; Baxter and Hauer 2000). In rivers where ground water upwelling does not occur, the major habitat variables influencing redd occurrence have been described as lower stream gradients, and smaller substrate diameter (Baxter and McPhail 1996).

The majority of bull trout migrate into streams for spawning between June and October, but can start as early as April and end as late as December and presumably depends upon latitude (McPhail and Murray 1979; Fraley and Shepard 1989; WDFW 1998; Ratliff 1992; Thiesfeld *et al.* 1996; Ratliff *et al.* 1996; Herman 1997; McLeod and Clayton 1997; Stelfox 1997; Mushens and Post 2000; Brenkman *et al.* 2001). Spawning occurs between July and October (Wissmar and Craig 1997; McLeod and Clayton 1997; Baxter and McPhail 1996; Boag and Hvenegaard 1997). Bull trout usually reach sexual maturity by their fifth summer, but different habitat and water temperatures can accelerate or delay sexual maturity (Berry 1994; Baxter 1997; McCart 1997). Mature bull trout can spawn each year but usually spawn in alternate years (Allan 1980; Fraley and Shepard 1989; Ratliff *et al.* 1996; Stelfox 1997).

The water temperature during spawning is around 5-9°C (Baxter and McPhail 1996; Herman 1997; Mushens and Post 2000).They prefer riffles and pool areas of rivers for

spawning (i.e., second to fourth order streams) (Fraley and Shepard 1989; Wissmar and Craig 1997; Herman 1997). Cobble is used as spawning beds (diameter 8-32 mm) and containing 22-33% fine sediment (Ratliff *et al.* 1996; Fernet and Bjornson 1997). Pebble sizes of 34-41 mm are often common in the spawning area (Wissmar and Craig 1997; Baxter and McPhail 1999) as well as gravel (Fernet and Bjornson 1997). Spawning depth ranges from 0.18 to 0.54 m (Kitano *et al.* 1994; Fernet and Bjornson 1997; Herman 1997; Reiser *et al.* 1997; Wissmar and Craig 1997; Baxter and McPhail 1999), with water velocities ranging from 0.12 to 0.66 m/s (Kitano *et al.* 1994; Fernet and Bjornson 1997; Reiser *et al.* 1997; Wissmar and Craig 1997; Baxter and McPhail 1999; Mushens and Post 2000).

Females fan the eggs for up to one hour prior to covering them with gravel (James and Sexauer 1997). Eggs develop in spawning gravel over winter and require 200-223 days for development (Shepard *et al.* 1984; Fraley and Shepard 1989). Downstream migration back to overwintering areas occurs in August to the last weeks of September (Boag and Hvenegaard 1997; McLeod and Clayton 1997).

Fry emerge in the spring (April to May) from the gravel redds. They then spend all their time amongst larger rocks, boulders, and interstitial habitat in shallow, low velocity portions of streams and rivers (Shepard *et al.* 1984; Pratt 1985, 1992; Goetz 1994; Baxter and McPhail 1997). Fry utilize shallow (0-15 cm), low bottom velocity (0-0.10 m/s), cobble sections of stream with an abundance of cover (submerged vegetation, small and large wood) using silt, pebble and cobble substrate types (Baxter 1997). Young-of-the-year overwinter in shallow pool areas of the river with no overhead cover or visible surface flow and associated with groundwater upwelling but within the interstial spaces of gravel and cobble (Boag and Hvenegaard 1997). Young-of-the-year bull trout utilize runs, riffles and pools equally, while 1+ year old fish prefer pool areas. Young-of-the-year bull trout stay along the channel margins while 1+ year old fish prefer the main channel area. Bull trout densities were greater in streams with maximum temperature below 14°C (Saffel and Scarnecchia 1995).

During early summer juveniles tend to be found in pools and then move into runs later in the year (Dambacher *et al.* 1992; Ratliff *et al.* 1996). A combination of the following variables are usually associated with juvenile habitat: high amount of shade, undercut banks, large woody debris, gravel and fines in riffles, low amounts of bank erosion, and large woody debris volume (Baxter and McPhail 1996; Goetz 1997; Dambacher and Jones 1997; Sexauer and James 1997; Jakober *et al.* 2000). Juveniles depend on cover more during the day than they do at night, showing nocturnal tendencies (Goetz 1997; Sexauer and James 1997; Jakober *et al.* 2000). They are usually found in water shallower than 1.0 m, and slower than 0.68 m/s (Baxter 1997; Fernet and Bjornson 1997; Goetz 1997; Jakober *et al.* 2000). Juveniles use nursery areas in main rivers along the channel margins (Oliver 1979; Dambacher *et al.* 1992), small side-channel and backwater areas (Baxter 1995), and are extremely substrate oriented. They are highly dependent on un-embedded cobble, gravel, boulder, overhanging vegetation and woody debris to provide cover (Pratt 1985; Fraley and Shepard 1989; Goetz 1994; Sexauer 1994; Ratliff *et al.* 1996; Baxter 1997; N. Mochnacz, personal communication). Bull trout are also found in

areas of undercut banks and riffles (N. Mochnacz, Natural Resources Institute, University of Manitoba personal communication 2002). Both fry and juveniles were found in water temperatures between 6 and 9°C (Bonneau and Scarnecchia 1996; Baxter 1997).

Bull trout overwinter in shallow pool areas of the river with no overhead cover or visible surface flow and associated with groundwater upwelling. Juveniles are associated with small streams for the first two years of life and then move into larger tributaries or lakes, depending on their life history type (Baxter and McPhail 1996).

Riverine (Fluvial)

Riverine bull trout spawn, rear and feed in rivers and streams. Adults require cold water to survive, they do not occur in water with a temperature greater than 15°C for great periods of time (Baxter and McPhail 1996). Bull trout have been found in warmer water (20.5°C) but can not compete well for resources at these temperatures and are usually migrating through the warm water en route to cooler waters (Adams and Bjornn 1997). The upper thermal limits for bull trout were tested using the acclimated chronic exposure (ACE) method. Fish held at temperatures higher than 22°C for over sixty days did not survive and did not feed. Compared to other salmonids in North America, bull trout have the lowest upper thermal limits (Selong *et al.* 2001). This life history type spawns in lower order streams but migrates downstream to live in large rivers and major tributaries, for much of their life, returning upstream to spawn. In southern populations bull trout are limited to cooler portions of rivers with deep pools and cover but in northern populations (e.g., Liard and Peace rivers) bull trout are more widely spread out and are less constrained by temperature and specific habitat (RL & L 1994; Baxter 1995). In the northwestern United States bull trout show nocturnal habits. They can be found in beaver ponds or areas of streams that are deep (40.9 +/- 1.6 SE cm), slow water (7.5 +/- 0.2 cm/s), and in or near the substrate during the day in shallower (35.0 +/- 0.5 cm) and slower water (5.1 +/- 0.2 cm/s) (Jakober *et al.* 2000). Both juveniles and adults overwinter in larger streams (McLeod and Clayton 1997). Bull trout caught in NT (Keele River) were caught in water 8°C and prefer deep pools with sand to pebble substrate (0.06-5cm diameter) (N. Mochnacz, Natural Resources Institute, University of Manitoba personal communication 2002).

Stream-resident

Stream-resident bull trout spend all their time in localized regions of streams and rivers, never migrating very far, even if other rivers are available to them (Baxter and McPhail 1996; McCart 1997). They are often associated with headwater streams in mountainous regions where there is cold water and velocity barriers to migration. These streams are usually smaller and have very steep gradients compared to those used by adfluvial and riverine types. Fish are usually found in deep pools and areas with in-stream cover (Baxter and McPhail 1996; McCart 1997). They overwinter in shallow pool areas of the river with no overhead cover or visible surface flow and associated with groundwater upwelling. Bull trout in West Castle River are found in areas of riffles and runs, with moderate velocity (>2.2 m/s), and pebble and gravel substrate (Boag and Hvenegaard

1997). In northwestern United States bull trout overwintered in pools and avoided fast-water habitats in fall and winter. Before ice forms fish select beaver ponds with large woody debris, and shift to beaver ponds and pools lacking large woody debris after surface ice forms. Where beaver ponds and surface ice are not present fish select pools with large woody debris and boulders during fall and winter (Jakober *et al.* 1998).

Adfluvial

Adfluvial bull trout spawn in rivers or outlets/inlets of lakes. After spawning adults and juveniles migrate downstream to feed and rear in the lake. They only return to rivers to spawn once they are mature or ripe. Juveniles remain in the natal streams for 1-3 years before migrating to the lake (Fraley and Shepard 1989; Baxter and McPhail 1996; Stelfox 1997; Mushens and Post 2000). Juvenile bull trout first migrate to the lake during April to August (Ratliff *et al.* 1996; Stelfox 1997; Mushens and Post 2000). As with other life history types adfluvial bull trout require cold water to survive (Baxter and McPhail 1996; Ratliff *et al.* 1996). Females in Kananaskis Lake mature at age six, while males mature between the ages of 6-7 depending on when their first migration to the lake occurred. Metolius River and Lake Billy Chinook (Oregon) bull trout mature at age 5 (Ratliff *et al.* 1996). Flathead River bull trout (Montana/BC) mature between the ages of 6-7 (Fraley and Shepard 1989). In the Wrigley Lake outflow (NT), fish were caught in September in cold water (8°C) in relatively deep pools (20-200+cm) with submerged woody debris, sand substrate and overhead cover (N. Mochnacz, Natural Resources Institute, University of Manitoba personal communication 2002). The lacustrine habitat requirements of adfluvial bull trout are discussed in detail in Richardson *et al.* (2001).

Anadromous

Anadromous bull trout populations migrate to the sea to feed (summer) and spawn and overwinter (fall) in lakes and streams. They have only been reported in southern areas where Dolly Varden co-occur. Their existence has been poorly studied and is relatively uncertain in general. No anadromous bull trout populations are known to occur in NT.

Dolly Varden (*Salvelinus malma* (Walbaum 1972))

Dolly Varden (or in earlier literature the western form of Arctic char) are found in rivers along the Beaufort Sea coast of Alaska, the Yukon, and Northwest Territories. In the NT Dolly Varden are found in the Big Fish, Rat and Vittrekwa rivers. They are not found in the NU (Reist *et al.* in prep.). Dolly Varden inhabit coastal waters along the north slope and move inland into streams and rivers (Glova and McCart 1974; McCart 1980; Craig 1989; Sandstrom 1995). They exhibit both anadromous and riverine resident (residual and isolated stream resident) life history types (McCart 1980; Sandstrom 1995; Reist *et al.* 1997). There has been much confusion concerning the identity of char in northwestern Canada and Alaska. There are no known populations of Dolly Varden in lacustrine environments in northwestern Canada. The lacustrine char west of the Mackenzie River are considered to be relict Arctic char (Reist *et al.* 1997). Dolly Varden originally

identified in earlier literature as being upstream in the Mackenzie River south to the NT-AB border are now considered to be Bull Trout (Reist *et al.* 2002).

Ecoregions - Dolly Varden are restricted to the Lower Mackenzie Ecoregion. Known populations occur in the Big Fish, Rat, and Vittrekwa rivers but the total extent of upstream distribution in the Peel, Arctic Red and Mackenzie River drainages is unknown at present (Reist *et al.* 2002).

Spawning occurs in the autumn (mid-August to October) in gravel habitats of upstream reaches of the rivers in areas fed by perennial springs (Hatfield *et al.* 1972; Bain 1974; Glova and McCart 1974; McCart 1980; DFO 2001; Reist *et al.* 2002). Females choose a suitable area for a redd in which to deposit their eggs. Mating pairs establish and defend territories and a few residual males usually shadow the mating pair. The residual males dart through the redd and release milt at the same time that the anadromous male does. After spawning is complete the fish move downstream to flowing water to overwinter (Craig 1977a; DeCicco 1989; Reist *et al.* in prep.). Spawning occurs in water depths of 20 cm or more in strong currents (0.6 m/s) and/or spring areas. Substrates utilized by Dolly Varden range from small gravel with some silt, to gravel and small boulders (2-10 cm dia) (Yoshihara 1973; McCart 1980). Dolly Varden are also known to spawn in pool areas in Fish Creek, Yukon Territory, and riffle areas with gravel substrates in Cache Creek, NT (Jessop *et al.* 1974). Spawning occurs at temperatures between 0-8°C (Dryden *et al.* 1973; Jessop *et al.* 1974; Jessop and Lilley 1975; Stein *et al.* 1973).

Eggs incubate for eight months over the winter and hatch in the spring and free swimming YOY emerge from the gravel in May or June and begin to feed along the stream margins (Bain 1974; Glova and McCart1974; McCart 1980). Juvenile rearing areas are largely unknown (DFO 2001). Young-of-the-year only undergo local movements and likely remain close to their natal spring for the first summer (Glova and McCart 1974; Armstrong *et al.* 1980; Reist *et al.* in prep.). Juveniles (age 1-3) are more active than YOY fish and travel throughout the river system feeding during the summer (Craig and Poulin 1975; Glova and McCart 1974; McCart 1980). Thirty immature Dolly Varden were caught over gravel in clear water by seine in Cache Creek (Dryden *et al.* 1973). In Fish Creek, a tributary of the Rat River, immature Dolly Varden were caught over gravel in clear water during August and September (Dryden *et al.* 1973). Juveniles in Alaska prefer shallow pools with low current velocities (below 0.3 m/s), with medium to coarse rock substrates, and are usually adjacent to swift flowing water (>0.5 m/s). Important cover features included instream vegetation, bank vegetation, shade, instream tundra slumps, and rock cover. Juvenile char are also found in braided floodplains with unvegetated channels (DenBeste and McCart 1984). After three years in freshwater the juvenile either switches to an anadromous life history or if it is a fast growing male, becomes sexually mature with a freshwater resident life history (see below) (Reist *et al.* in prep.). Juveniles first go to sea at ages 3-4 but can go as young as age 2 and as late as age 5 (Yoshihara 1973; Bain 1974; McCart 1980; Gillman and Sparling 1985; Bond and Erickson 1989).

Downstream migration to the sea begins as the ice cover on the river melts in the spring, usually between the beginning of June and beginning of July (Glova and McCart 1974; McCart 1980). The larger fish tend to migrate downstream ahead of the juvenile smaller fish (Glova and McCart 1974). The youngest mature anadromous Dolly Varden in Phillips Bay was six years of age (Bond and Erickson 1989). At sea Dolly Varden remain close to shore moving along the shore line in about 1.5 m water depth feeding on marine and anadromous fish rather than offshore (McCart 1980). Their coastal migrations can be quite lengthy, up to 250 km in some instances (Glova and McCart 1974). In Alaska migration of up to 485 km have been reported (DeCicco 1989). Upstream migration begins in the first week of August in the Babbage (YT) and Big Fish (NT) rivers and trails off in the first week of September (Sandstrom 1995). Current-year spawners return early beginning in July and early August followed by non-spawners in mid to late August, while younger anadromous fish began to return in late August and early September. Most Dolly Varden have left the coast by September (Glova and McCart 1974; Griffiths *et al.* 1975, 1977; McCart 1980; Gillman and Sparling 1985; Bond and Erickson 1989; Sandstrom 1995).

Both anadromous and residual adults overwinter in the areas of the river where the presence of a thermal spring maintains a section of open water throughout the winter (Bain 1974; Glova *et al.* 1974; McCart 1980; Craig 1989; Reist *et al.* in prep.). These habits are shallow (0.5 m average depth). This area is extremely important because the rest of the river freezes to the bottom. The entire population of Dolly Varden (eggs, juveniles, adults and residuals) as well as any other species living in the river spend 6-8 months of the year in this small pool habitat which is either open water or located under the ice (Sandstrom 1995; Reist *et al.* in prep.). In the Big Fish River Dolly Varden have been caught in "ice tunnels" that form in the core of the aufeis field and this is an unique overwintering habitat in this river due to the warmer spring temperatures (15°C) (Sandstrom 1995). In Fish Creek, a tributary of the Rat River, mature and immature Dolly Varden were caught over gravel in clear water during August and September (Dryden *et al.* 1973).

Anadromous individuals become sexually mature adults at age 2 for males, but not usually until age 5, with all mature at age 8 or 9 (Jessop *et al.* 1973; Bain 1974; Glova and McCart 1974; McCart 1980; Gillman and Sparling 1985; Sparling and Stewart 1986; DFO 2001). Females mature a little later at ages 4-9 (McCart 1980; Gillman and Sparling 1985). Anadromous Dolly Varden do not spawn each year and during the year that they will spawn they may or may not migrate to sea that summer (Glova and McCart 1974; McCart 1980; DFO 2001; Reist *et al.* in prep.). Maximum age of Dolly Varden caught in Phillips Bay was 14 years (Bond and Erickson 1989).

Residual (non-anadromous) Dolly Varden occur in the Big Fish River among others, but have not been described in the Rat River (DFO 2001; Reist *et al.* in prep.). Resident males mature as early as age 2, and all are mature by age 6. They are smaller in size than anadromous Dolly Varden when they mature (McCart 1980; DFO 2001). Life history of the residual fish is not well studied. They disperse in the summer to feed in tributaries and return to the spawning areas in the fall (Craig and Poulin 1975; Reist *et al.* in prep.).

Residual populations are composed almost exclusively of males and reside in the headwater streams for their entire lives.

Isolated populations of Dolly Varden occur in the NT in Cache Creek and also in the Babbage River (YT) above respective waterfalls (Reist *et al.* in prep.), and occur in Alaska as well. In isolated populations the oldest fish are 5-11 years of age. The youngest mature males are two years of age, the youngest mature females are age 3, and 100 percent maturity occurred at age 4-5 for both sexes (McCart and Craig 1973; Bain 1974; McCart and Bain 1974). Males and females spawn every year in isolated populations. Spawning occurs later than in anadromous populations. Dolly Varden taken in early November were still green suggesting the spawning season had just started. The Babbage River isolated population spawns in mid-October (Bain 1974) and in Cache Creek during November and December (McCart and Bain 1974). In the isolated spring area the water temperatures ranged from 3.5 to 8°C, depth ranges from 15-45 cm deep, and is very fast flowing water > 1.0 m/s (McCart and Craig 1973). Eggs develop more quickly in isolated populations due to the warmer waters of the springs contain (Bain 1974; McCart and Bain 1974; McCart 1980).

Lake trout (*Salvelinus namaycush* (Walbaum 1792))

Lake trout are found throughout the NT and NU including many ofthe Arctic Islands (Baffin, South Hampton, King William, Victoria, and Banks) (McPhail and Lindsey 1970; Lee *et al.* 1980; Scott and Crossman 1973; Babaluk *et al.* 1997). They occur primarily in large deep lakes but can occasionally be found in large clear rivers (Loftus 1958; McPhail and Lindsey 1970; Scott and Crossman 1973; Lawrence and Davies 1978; Morrow 1980). Lacustrine and adfluvial life history types are known (Scott and Crossman 1973; Goodyear *et al.* 1982). For a complete description of lake trout lacustrine life history and habitat requirements please refer to Richardson *et al.* (2001).

Ecoregion – Lake trout occur in the Lower and Upper Mackenzie, Western Arctic Islands, North Arctic and East Arctic ecoregions.

Stream and river spawning, although rare, may occur in the Arctic. Lake trout are known to spawn in the mouth of the Hay River in September to early October (Scott and Wheaton 1954; MacDonald and Stewart 1980). They are said to ascend the rivers of Lake Nipigon to spawn in Sturgeon River (Dymond 1926). In eastern Lake Superior lake trout spawned in six different tributaries (e.g., Montreal, Dog, Puckasaw and Eagle rivers). In these streams the lake trout migrated from 180 m to 3.2 km before reaching the spawning area. Substrates used for spawning consisted of large boulders mixed with gravel in eddies (Loftus 1958). Paterson (1968) describes lake trout spawning in the outlet to Swan Lake. The substrate consisted of rubble 3-8 cm in diameter, and depths varying from 15-50 cm. River spawning also occurs in Cedres Brook, Quebec (Seguin and Roussel 1968 as cited in Martin and Olver 1980) at depths of 30-61 cm with substrate consisting of gravel, rubble, and boulders up to 46 cm in diameter. Spawning may occur in the Kobuk River of Alaska, but this has not been verified (Morrow 1980). Spawning is thought to occur in the wide and slow sections of the Back River, NU but not every year. Lake Trout

have also been found in the Falls, Thelon and Simpson rivers (MacDonald and Stewart 1980).

Lake trout are found throughout northern river systems, but it is not known to what extent the riverine habitat is used (i.e., possibilities include migration corridors between lakes, feeding areas, spawning areas and nursery areas). More research into lake trout use of riverine areas is clearly necessary.

Inconnu (*Stenodus leucichthys* (Guldenstadt 1772))

In North America the inconnu ranges from the Kuskokwim River in Alaska to the Anderson River, NT (Scott and Crossman 1973). They are not known to occur in the NU but are found in the NT primarily in the Mackenzie River drainage basin. They are found upstream in the Mackenzie Basin as far as Fort Nelson on the Liard River and through Great Slave Lake up to the rapids at Fort Smith on the Slave River (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). They are found primarily in large muddy rivers and associated lakes (McPhail and Lindsey 1970; Percy 1975). Inconnu in arctic Canada exhibit anadromous and adfluvial life history types (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Howland 1997) and may also exhibit a riverine life history type similar to that described in Alaska (Alt 1988; Howland *et al.* 2000). Anadromous inconnu spawn in rivers associated with the coast while freshwater resident populations in lakes spawn in adjacent rivers (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973). For information concerning the lacustrine habitat requirements refer to Richardson *et al.* (2001).

Ecoregion - Inconnu are found in the Lower and Upper Mackenzie River and North Arctic ecoregions.

Anadromous

Inconnu spawn in the Peel, Arctic Red, and Anderson rivers (Stein *et al.* 1973; Howland 1997). Spawning in Alaska occurs during late September in the swift main current of the river along the bank and in the middle of the river. Water depth was between 1.2 and 2.7 m. The bottom was composed of differentially sized, coarse gravel with no silt and some sand (Alt 1969). After spawning there is a distinct downstream migration of inconnu during October (Jessop *et al.* 1974; Howland 1997).

Eggs incubate on the spawning grounds over the winter months, hatching in the spring. The young are most likely washed down stream with the spring run off. In the Anderson River estuary inconnu are common in the summer. Young-of-the-year first appeared in mid-July and were abundant into early August. Ages of fish in the estuary ranged from 0-15 although most fish caught were YOY or ages 5-8. None of the fish were sexually mature (Bond and Erickson 1991).

Juveniles and resting adults can be found in Tuktoyaktuk Harbour during the summer but they are not common compared to other species. Some have been taken offshore in

Kugmallit Bay, but they are more common in shallow freshened nearshore areas during the summer months. Those fish caught in Tuktoyaktuk Harbour range from 4-17 years of age (Bond 1982). Hopky and Ratynski (1983) reported the same findings in Tuktoyaktuk Harbour, inconnu were not common in the catches, but those caught were more common inshore than offshore. A few inconnu have been captured in Liverpool Bay in July and August (Bond and Erikson 1993). Inconnu were abundant during the summer in Mallik Bay and Mason Bay throughout the open water season with most fish not being ready to spawn. Large concentrations of immature inconnu reside in the outer Delta during the summer (Percy 1975). Inconnu undergo the least extensive coastal migration of the five anadromous coregonine species occurring in the southern Beaufort Sea region (Reist and Bond 1988). The coastal distribution of young inconnu is severely restricted by salinity (Bond and Erickson 1992).

Mature inconnu are believed to spawn only every two to four years and seldom venture into marine environments in the year of spawning (Scott and Crossman 1973; de Graaf and Machniak 1977; Jones and Den Beste 1977). Bond (1982) suggests the lack of current-year spawners in Tuktoyaktuk Harbour during the summer may be due to the lengthy migration that they must undergo from their overwintering grounds in the Mackenzie Delta upstream to spawning areas. Only a few current-year spawners were caught in the coastal areas of Wood Bay during the summer (Bond and Erickson 1992). Current spawners forego feeding in the estuary and spend their summer migrating to the spawning grounds. This is supported by the fact that inconnu found during July and September in an upstream area of the Mackenzie River (Rampart Rapids) were aged 5-24 and all were mature except for three fish. Also all fish in the Little Chicago area (Mainstem Mackenzie River) caught in September were mature (Stewart *et al.* 1997). Inconnu are the first species to migrate through the Mackenzie Delta on their way to spawning grounds. They reach the Arctic Red River by early July and the catch decreases gradually over the summer as pre-spawning fish proceed further upstream to spawning sites as far as the lower Liard River (McLeod *et al.* 1979; Howland 1997).

Mackenzie River inconnu begin to achieve sexual maturity at age 6 (Stein *et al.* 1973; Percy 1975). In Alaskan streams males (5-9 years) mature at younger ages than females (7-12 years) (Alt 1973). Percy (1975) recorded the oldest inconnu as 16 years of age but an inconnu caught in Wood Bay/Anderson River was 39 years old (Bond and Erickson 1992).

Tuktoyaktuk Harbour and Kugmallit Bay are important overwintering areas for inconnu (Bond 1982) as well as the regions of the outer Mackenzie Delta (Percy 1975; Jessop and Lilley 1975; Mann 1975; de Graaf and Machniak 1977).

Adfluvial

Inconnu in Great Slave Lake are not anadromous, but undergo an adfluvial life history (McPhail and Lindsey 1970; Howland 1997). They spawn in the Slave River (Fuller 1947, 1955; Tripp *et al.* 1980, 1981; McLeod *et al.* 1985; Tallman *et al.* 1996a,b) as well as in the Buffalo, Hay, Little Buffalo and Talston rivers (Fuller 1955; Scott and Crossman

1973; Rawson 1947; McLeod *et al.* 1985). Inconnu in the Slave River enter during mid-August with peak movements during the end of August or early September (water temperatures between 20-10°C). Spawning occurs in early and mid-October (water temperatures 2.5-4.5°C). After spawning near Fort Smith below the Rapids of the Drowned, inconnu move downstream from mid-October to the end of October (water temperature 5°C) to Great Slave Lake where they overwinter and spend the following summer. The young hatch in the spring and are thought to remain in the river for at least two years before descending to Great Slave Lake (Scott and Crossman 1973). In May and June, current-year spawners along with resting individuals and immature fish congregate at the mouth of the Slave River. By July non-spawners and immature individuals disperse back into deeper lake areas until the next year. Spawners hold at the mouth of the river through July until they begin their migration in August (Rawson 1947; McLeod *et al.* 1985; Tallman *et al.* 1996a; Howland 1997).

Males in the Slave River first mature at age 5-6, while females mature later at ages 7-9. The oldest fish caught was 13 years old (Fuller 1955; Tallman *et al.* 1996b).

Arctic grayling (*Thymallus arcticus* (Pallas 1776))

The Arctic grayling is found throughout the mainland NT and NU but has not been recorded from the Arctic Islands (McPhail and Lindsey 1970; Scott and Crossman 1973; McCart and DenBeste 1979; Lee *et al.* 1980; Ford *et al.* 1985). It is commonly found in rivers, streams and lakes throughout the north with clear cold waters (McPhail and Lindsey 1970; Scott and Crossman 1973; Ford *et al.* 1985). They exhibit riverine, adfluvial and lacustrine life history types (McPhail and Lindsey 1970; Scott and Crossman 1973; Jessop and Lilley 1975; Krueger 1981). Arctic grayling spawn in the spring in both rivers and lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Machniak and Bond 1979; Ford *et al.* 1985). They also use streams as migration corridors from one lake to another (Martin 2001). For information concerning lake habitat requirements and life history please refer to Richardson *et al.* (2001).

Ecoregion – The Arctic grayling is found in the Lower and Upper Mackenzie River, North Arctic, and East Arctic ecoregions.

Riverine

Arctic grayling spawn in the spring, and frequent clear streams and lakes tributary to the Mackenzie River (McCart *et al.* 1976). Arctic grayling spawn from mid-May to early June at the time that the ice-cover begins to break up (McPhail and Lindsey 1970; Scott and Crossman 1973; de Bruyn and McCart 1974; Tripp and McCart 1974; Craig and Poulin 1975; Kratt and Smith 1977). Adults migrate from lakes and larger rivers into smaller streams to spawn over gravel or rocky bottoms (McPhail and Lindsey 1970; Scott and Crossman 1973). The preferred spawning substrate is gravel but a percentage of sandy bottom (<15-20%) is also found in some spawning areas (Scott and Crossman 1973; Stuart and Chislett 1979; Kratt and Smith 1980; Machniak *et al.* 1980; Gardiner

1984; Beauchamp 1990). In Alaska spawning has been recorded to occur over gravel riffles, pools and in highway culverts (Reed 1964; Scott and Crossman 1973; Beauchamp 1990). Grayling spawn in areas with surface current velocities less than 1.4 m/s, varying water depths and relatively small, unimbedded gravels about 2.5 cm in diameter. No redd is constructed and the eggs attach to the substrate and may be covered by 5 cm of substrate (Reed 1964; Tack 1971; Krueger 1981; Beauchamp 1990). Once spawning is finished there is a post-spawning run of Arctic grayling out of the creek into the adjoining river which occurs from mid to late June (Chang-Kue and Cameron 1980). Spawning occurs at water temperatures of 7-10°C (Scott and Crossman 1973; Craig and Poulin 1975; Beauchamp 1990). Males arrive on the spawning ground first and establish and defend a rectangular territory with the long axis parallel to the stream flow. If they can not establish a territory then they move downstream into a refuge area where females wait too. Females cruise through the males' territories looking for mates. The majority of spawning occurs during the midday to late afternoon periods (Beauchamp 1990; Ford *et al.* 1995). After many lateral displays the male drapes his dorsal fin over the female and they spawn which can disturb the bottom sediment slightly due to the vigorous vibrating by both fish (Beauchamp 1990). Spawning takes place over a 2-3 week period and there is no parental care of the eggs or young (Ford *et al.* 1995). There is some homing to natal streams for spawning (Tripp and McCart 1974).

Young hatch within 16-18 days at 9°C (McPhail and Lindsey 1970) or within 8-32 days at 15.5-5.8°C respectively (Krueger 1981; Kratt and Smith 1977). Newly hatched alevins spend a further three to five days under the substrate (Ford *et al.* 1995). Fry are first collected from late June to early July (Tripp and McCart 1974; Craig and Poulin 1975; Chang-Kue and Cameron 1980). They reside in semi-deep pools and side channels with water depth of 30-50 cm, over boulder, cobble, silt and sand substrates and water velocities less than 0.8m/s (Vascotto 1970; de Bruyn and McCart 1974; Stuart and Chislett 1979; Lee 1985; Kaya 1989; Ford *et al.* 1995). Initially the fry school together but within three weeks begin to exhibit some antagonistic behaviour toward one another (Vascotto 1970; de Bruyn and McCart 1974; Kratt and Smith 1977). Cover (rocks) is also very important (Vascotto 1970; Ford *et al.* 1995), but Lee (1985) noted that when frightened larval Arctic grayling did not utilize available cover. Young-of-the-year remain in their natal stream for up to 15 months (Ford *et al.* 1995) but can leave as early as September (Craig and Poulin 1975). Young-of-the-year are distributed throughout the middle and delta areas of the Firth River, YT as well as the lower halves of Trail (NT) and Crow (YT) rivers during the summer (de Bruyn and McCart 1974).

Juveniles prefer areas of sand and gravel (Vascotto 1970). In Alaska juveniles were found in water temperatures ranging from 5-17°C. Cover, when used, was most often rocks, and to a lesser extent cutbanks, loose gravel, overhanging vegetation, instream vegetation and shade. Juveniles were found in the highest densities in habitats of slow-moving water, shallow depth, and substrates of silt, gravel and rubble with some sand, but especially in areas with silt substrates and velocities of zero at depths of 20-80 cm. Some juveniles were also caught in riffle areas with boulders and cobble in water 20-30 cm deep. As fish became longer they tended to occupy deeper and faster water in areas close to shore, backwater areas, pools or side channels (Falk *et al.* 1980; Dahlke 1983; DenBeste and

McCart 1984; Lee 1985; Low and Read 1987). Arctic grayling prefer streams with low turbidity (DenBeste and McCart 1984). Juveniles are distributed throughout the middle and delta areas of the Firth River (YT) as well as the lower halves of Trail (NT) and Crow (YT) rivers during the summer. In the Babbage River (YT) fry and juveniles were found below the falls, but few adult fish were found (de Bruyn and McCart 1974). After they reach one year of age they undergo yearly migrations between their natal stream (arrive 2-4 weeks after the adults have spawned) and their overwintering areas (Ford *et al.* 1995). Some juveniles remain in their natal stream feeding, but some move to other areas of the river system. Those that stay in their natal streams all summer leave in the middle of September with numbers dropping by the end of September to go to their overwintering areas (Craig and Poulin 1975).

Adult Arctic grayling migrate approximately 60 km to 320 km from overwintering areas to the spawning grounds (Reed 1964; Tripp and McCart 1974). Adults remain in the Donnelly River system for about a month after spawning and then begin to move downstream and disperse to other areas of the Donnelly River or even into the Mackenzie River by the beginning of October (Tripp and McCart 1974). During the summer feeding period, after spawning, adults prefer areas of rubble and gravel and are found over fine-grained and coarse substrates, while medium-grained substrates are avoided (Vascotto 1970; DenBeste and McCart 1984). Adult Arctic grayling often used rocks for cover and water with high velocities and deep depths. They prefer velocities between 0.61 m/s – 1.08 m/s but can be found in water from 0-1.3 m/s. They prefer depths of 110-152 cm, but can be found in shallow areas 23-91 cm. They use debris, rubble (7.62-12.7 cm) and cobble (>12.7 cm) as cover type. Fourteen percent use overhanging riparian, undercut banks, and deadfall as cover, while only seven percent use aquatic or emergent vegetation, or no cover at all (DenBeste and McCart 1984; Schmidt *et al.* 1984; Liknes and Gould 1987).

Alaskan Arctic grayling in streams prefer clear water as compared to turbid areas (Schmidt *et al.* 1984). Adults require deep pools or lakes for overwintering (Ford *et al.* 1995). Overwintering sites on the North Slope (YT) are spring areas in the upper Firth River, Joe Creek and Canoe Creek, and some grayling remain here all summer long. In the Babbage River grayling utilize perennial spring areas to overwinter or the tundra lakes (de Bruyn and McCart 1974). In the Tanana River system, Alaska, Arctic grayling spend the winter in the main river, and by April are aggregating at the mouths of small tributary streams. Arctic grayling in tributaries of the Kavik River, Alaska use spring fed areas to overwinter in. They leave these areas shortly after spring thaw to spawn (Craig and Poulin 1975).

Arctic grayling can mature as early as age 2 or as late as nine years of age (de Bruyun and McCart 1974; Tripp and McCart 1974; Chang-Kue and Cameron 1980; Armstrong *et al.* 1986; Ford *et al.* 1995). In the Kakisa River, Arctic grayling mature at age 3-4 for males and 4-5 for females (Falk *et al.* 1980; Dahlke 1983; Low and Read 1987). The maximum age for grayling ranges from 11-22 years depending on the river system they inhabit (Scott and Crossman 1973; de Bruyun and McCart 1974; Tripp and McCart 1974; Chang-Kue and Cameron 1980). Once mature it is likely that Arctic grayling spawn every year

(de Bruyn and McCart 1974; Ford *et al.* 1995). Arctic grayling have been caught in coastal areas in the Anderson River Estuary (Bond and Erickson 1991,1992). During the summer adults from the Mackenzie River and its tributaries, and the Great Bear River and its tributaries use the Great Bear River as a feeding area (McCart 1982). One riverine population is known to use a lake (Three Day Lake) to spawn in during the spring. After spawning they move back into the Great Bear River to feed and overwinter (Chang-Kue and Cameron 1980).

Adfluvial

Adfluvial populations use the same habitat for spawning as do riverine populations. They differ in the areas that they use to feed and overwinter. Young, juveniles and adults are found in lakes throughout their life history until they move into rivers to spawn (see Richardson *et al.* 2001).

Smelts (Osmeridae)

Pond smelt (*Hypomesus olidus* (Pallas 1814))

The pond smelt is reported to occur in NU in the Rae River (Sutherland and Golke 1978) and occurs within the NT in the lower portions of the Mackenzie and Peel rivers, lakes and rivers of Tuktoyaktuk Peninsula, and is found as far south as Great Bear Lake (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Bond 1992; Lawrence *et al.* 1984; De Graaf 1986; Platts and Millard 1995). It is commonly found in rivers, streams and lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; De Graaf 1986) and exhibits both riverine and lacustrine life history types (Scott and Crossman 1973; De Graaf 1974; 1986). For descriptions of lacustrine habitat requirements please refer to Richardson *et al.* (2001).

Ecoregion – The pond smelt is found in the Lower Mackenzie and North Arctic ecoregions.

Pond smelt spawn in rivers and streams in late June. There is very little information on riverine populations in Canada. In Alaskan streams spawning occurs over pebble bottoms (Morrow 1980). In Japan stream spawning occurs over gravel and sand (Katayama and Okata 1995). Russian pond smelt do not construct nests, eggs are laid or settle on aquatic vegetation or submerged organic debris. Pond smelt can spawn in waters with velocities up to 0.7-0.8 m/s and in depths less than one meter (Gritsenko *et al.* 1984). Eggs are adhesive and hatch in about 18 days at 10°C (McPhail and Lindsey 1970; Scott and Crossman 1973; Gritsenko *et al.* 1984).

In Alaska juvenile pond smelt were caught in rivers over sand and mud bars (Platts and Millard 1995). Few pond smelt live longer than five years (Lee *et al.* 1980). Pond smelt have been found in the Tuktoyaktuk Harbour, mouth of the Freshwater and Mayogiak creeks, near Tuktoyaktuk Island, Shallow Bay near the mouth of the West Channel, and along Richards Island during the spring and summer (Percy 1975; Bond 1982; Hopky and

Ratynski 1983; Lawrence *et al.* 1984). Fall downstream migrations have been recorded in Kukjuktuk Creek (Lawrence *et al.* 1984).

Rainbow smelt (*Osmerus mordax* (Mitchill 1846))

Rainbow smelt are found in the NT in the Mackenzie Delta ranging upstream to the confluence of the Arctic Red River (Wynne-Edwards 1952; Scott and Crossman 1973). There are no records of this species for the NU. It is associated with rivers, streams, lakes and inshore coastal areas (Lee *et al.* 1980; Scott and Crossman 1973; Scott and Scott 1988). Rainbow smelt exhibit anadromous, freshwater-resident lacustrine and adfluvial life history types (Scott and Crossman 1973; Bruce 1975; Buckley 1989; Scott and Scott 1988). Anadromous populations spawn in rivers and streams above the head of the tide (McKenzie 1964; Scott and Crossman 1964; Morrow 1980; Scott and Scott 1988; Buckley 1989). Freshwater-resident populations may also spawn in rivers and streams joined to lakes (Rupp 1965; Scott and Crossman 1973; Bruce 1975; Lee *et al.* 1980; Morrow 1980; Nelbring 1989). They prefer cool clear waters (Lee *et al.* 1980) and are only found in flowing waters of rivers during spawning time (Scott and Crossman 1973).

Ecoregion – The rainbow smelt is found in the Lower Mackenzie ecoregion.

Life history patterns are much the same between anadromous and adfluvial life history types (Scott and Crossman 1973). Both these types only spawn in rivers, and consequently this information has been pooled due to the similarity. There is very little specific information concerning northern populations. For information concerning lacustrine habitat requirements refer to Richardson *et al.* (2001).

Adults leave the sea or lake and ascend freshwater streams to spawn not long after the ice is out in the spring (Scott and Crossman 1973; Lee *et al.* 1980). Movement into streams for spawning occurs when the water temperature reaches 2-4°C or higher (Morrow 1980). Adult anadromous rainbow smelt enter the Mackenzie River as early as March (Percy 1975) to spawn near the head of the delta in the vicinity of the Arctic Red River (Stein *et al.* 1973). After spawning the adults move back to the summer feeding areas of Kugmallit Bay (Bond 1982). In the Miramichi River, NB, rainbow smelt move into the river under the ice during March and reach freshwater by the end of April. Spawning lasts from April until early June (McKenzie 1964). Anadromous rainbow smelt concentrate at the mouth of the Colville River, Alaska, during February and March, with the fish moving up into the river during April and May (Haldorson and Craig 1984). In isolated Newfoundland populations spawning occurs in May in rivers associated with the lake in 60-120 cm of water, with eggs deposited on debris and rocks (Bruce 1975).

Males reach the spawning grounds first, followed by the females. Spawning generally occurs at night. Eggs sink to the bottom and become attached to rocks, gravel, vegetation, or each other (Scott and Crossman 1973; Lee *et al.* 1980; Scott and Scott 1988). After spawning has finished for the evening the smelt move downstream back to the lake or estuary and remain there during daylight. Spawning takes place over sandy gravel, pebbles and rocks in swift water. Larger fish spawn first and the spawning season can

extend over several weeks or months. Many of the fish die after spawning, but those who live spawn again the next year (Scott and Crossman 1973; Morrow 1980), at least in southern populations. There is no parental care of the eggs or young (Bruce 1975).

Hatching occurs in about 29 days at 6-7°C and ten days at 15°C (McKenzie 1964). Fry are not strong swimmers and are swept down into the estuary or lake from which their parents originated (Morrow 1980; Bond 1982; Scott and Scott 1988). Young-of-the-year and juveniles in the Miramichci River, NB, can be caught throughout the main river, bay and estuary during the spring and summer (McKenzie 1964).

Rainbow smelt are essentially schooling, pelagic fishes, inhabiting mid-water areas of lakes or inshore coastal waters (Scott and Crossman 1973). By mid-August in the Miramichi River, NB, they are no longer present in the river, however, by September all sizes of smelt are found 5-8 km up the river where they overwinter (McKenzie 1964). Anadromous rainbow smelt overwinter along the coastal areas of the Beaufort Sea (Haldorson and Craig 1984) including Kugmallit Bay (Bond 1982). Maturity is reached from ages 6-7 in northern anadromous populations (Scott and Crossman 1973; Haldorson and Craig 1984). East coast rainbow smelt (adfluvial) mature earlier at 1-2 years of age and only reach a maximum age of five years (Bruce 1975). Anadromous rainbow smelt in the Beaufort Sea coastal area ranged in age from 1-15 (Bond 1982; Haldroson and Craig 1984; Lawrence *et al.* 1984).

Mooneyes (Hiodontidae)

Goldeye (*Hiodon alosoides* (Rafinesque 1819))

The goldeye has limited distribution in the NT and has not been reported in NU (Kennedy and Sprules 1967; McPhail and Lindsey 1970). In the NT it has been reported in small numbers from the mouth of the Mackenzie River upstream to Great Slave Lake. It is also present in the Liard, Slave and Athabasca rivers (Kennedy and Sprules 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Tripp *et al.* 1981). Goldeye are capable of living in very turbid water and can be found in larger rivers, marshes, ponds and lakes (Sprules 1954; Kennedy and Sprules 1967; McPhail and Lindsey 1970; Scott and Crossman 1973; Nelson and Paetz 1992). They exhibit riverine and adfluvial life history types (Kennedy and Sprules 1967; Hatfield *et al.* 1972; Stein *et al.* 1973). For information concerning the life history and habitat requirements of the lacustrine portion of the goldeye's life history please refer to Richardson *et al.* (2001).

Ecoregions – Goldeye are found in the Lower and Upper Mackenzie River ecoregions.

Spawning occurs in the spring from May to the first week of July (Battle and Sprules 1960; Scott and Crossman 1973; Donald and Kooyman 1974; Lee *et al.* 1980) at water temperatures between 7-14.5°C (Donald and Kooyman 1974; Lee *et al.* 1980). It occurs in pools in turbid rivers at night (Scott and Crossman 1973; Lee *et al.* 1980). Spawning substrate consists of shallow firm-bottomed areas of rivers (Scott and Crossman 1973). Rivers with gravel, muck and sand bottoms are utilized for spawning (Sprules 1946).

Eggs are semibouyant and hatch in approximately two weeks (Sprules 1954; Battle and Sprules 1960; Scott and Crossman 1973; Donald and Kooyman 1977).

Young-of-the-year have been caught in rivers in areas of large eddies as well as areas where water movement is nil and shallow in depth. They preferred substrates of clay but were also caught in areas with sand substrate (Kristensen 1981). Young-of-the-year in Manitoba were found in 120 cm of water on sand bottoms in eddies (Sprules 1946). Juvenile fish migrate along rivers and lakes during the summer feeding, and then return to their overwintering grounds in the late fall (Donald and Kooyman 1977).

Adults spawn annually and reach maturity in northern regions from ages 6-9 for males and 7-10 for females (Battle and Sprules 1960; Kennedy and Sprules 1967; Scott and Crossman 1973; Tripp *et al.* 1981). The maximum age for a goldeye is 14 years in Alberta (Kennedy and Sprules 1967; Lee *et al.* 1980) and 23 years in the Slave River (Tripp *et al.* 1981). Goldeye habitat consists of quiet turbid water of large rivers, usually in eddies. They overwinter in deeper areas of lakes and rivers (Sprules 1954; Scott and Crossman 1973). Adult goldeye overwinter in the Peace River (Donald and Kooyman 1977). In Manitoba goldeye were caught in the mouths of rivers with rapid flow and muddy bottoms (Sprules 1946).

Pike (Esocidae)

Northern pike (*Esox lucius* (Linnaeus 1758))

The northern pike is found in the NT and the NU, although it has not been reported from the northern Keewatin region or the Arctic Islands (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973). It generally inhabits weedy areas of slow meandering rivers and bays of lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; Becker 1983). Northern pike are known to exhibit riverine, adfluvial and lacustrine life history types (McPhail and Lindsey 1970; Cheney 1971; Stein *et al.* 1973; Bregazzi and Kennedy 1980; Holland and Huston 1984). For information concerning lacustrine northern pike habitat requirements please refer to Richardson *et al.* (2001). Northern pike are known to spawn in the back waters of rivers as well as in lakes (Diana *et al.* 1977; Bond and Machniak 1979; Holland and Huston 1984; Kozmin 1981). They are not adapted for life in strong currents (rivers) and they occur more frequently in lakes (Crossman 1978).

Ecoregion – Northern pike are found in the Upper and Lower Mackenzie, North Arctic and East Arctic ecoregions.

Northern pike will spawn in rivers, streams, ditches, marshes, and inshore and offshore areas of lakes in areas with aquatic vegetation (Machniak 1975b). Spawning occurs in the Slave River mainstem and delta in the spring after the ice melts (May) (Hatfield *et al.* 1972; Tripp *et al.* 1981). In the Rabbitskin and Arctic Red rivers spawning occurs from May 29-June 18 (Jessop *et al.* 1973). Spawning migrations in the Kakisa and Hay rivers, and in Paulette Creek (Great Slave Lake) occur at the time of ice break-up with spawning occurring during May and the beginning of June (Falk and Dahlke 1975). Generally in the

Mackenzie River valley spawning occurs from late May in the southern valley to early July in the northern valley (Stein *et al.* 1973). Spawning in Alaska occurs from mid-May to mid-June (Cheney 1971). Strong currents (> 1.5 m/s) can block pike spawning migrations (Dryden and Jessop 1974). Important spawning areas in the Mackenzie River are tributary mouths with flooded emergent vegetation with water temperatures ranging from 4-16°C and in less than 30 cm of water (Hatfield *et al.* 1972; Stein *et al.* 1973; Ford *et al.* 1991). The female and up to three males swim side-by-side over the dense submerged vegetation, in areas of zero water velocity, releasing eggs and milt. The fertilized eggs are adhesive and attach to the vegetation (Scott and Crossman 1973; Ford *et al.* 1991). In Alaskan Rivers pike prefer to spawn in water less than 60 cm deep (minimum of 5 cm), with submergent and/or emergent vegetation, with little to no current, at water temperatures between 5.6 and 12.8°C, and mud substrate with a vegetation mat (Cheney 1971; Casselman and Lewis 1996). Northern pike also use vegetation consisting of hummocks of grasses and sedges to spawn over with a well oxygenated vegetative detritus substrate (Casselman and Lewis 1996).

Eggs hatch in 12-14 days. After hatching the young immediately attach to flooded vegetation with an adhesive gland on top of the head until the yolk sac has been absorbed (Scott and Crossman 1973). Nursery habitat is in the area of spawning and consists of dense submergent and emergent aquatic vegetation in back eddies or at the mouths of tributary streams (Jessop et al 1973; Stein *et al.* 1973; Casselman and Lewis 1996). Young remain in the spawning area for several weeks after hatching (Machniak 1975b). Young-of-the-year northern pike are abundant in the East Channel, Middle Channel and most of the minor channels of the Slave River Delta during late summer and fall (Tripp *et al.* 1981). In the Mississippi River YOY northern pike were more abundant in areas of submerged vegetation as opposed to emergent vegetation areas and areas with no vegetation (Holland and Huston 1984). Most pike fry emigrated from their natal streams (e.g., Bluefish Creek) in the latter half of July into slower water, and weedy areas of the main river (e.g., Mackenzie River), but some remained in tributary streams (Jessop and Lilley 1975). Pike are ambush predators and require cover in the form of aquatic plants, tree stumps, and fallen logs, and are usually most active during the daylight (Inskip 1982). Juveniles are typically found in depths less than 2 m, over mud and silt substrate with aquatic vegetation used as cover (Inskip 1982; Ford *et al.* 1991).

After spawning adults may remain in the spawning stream or move downstream to the associated river or lake. There is an increase in abundance of pike in the Slave Delta from spring to fall. Northern pike move downstream during the open water period to feeding and overwintering areas in the Slave River delta or Great Slave Lake. In the Mackenzie Delta area pike move out of the many shallow delta lakes and creeks during mid-August and freeze-up in September. They move to overwintering areas in the Mackenzie River and Delta Channels (Stein *et al.* 1973; Jessop and Lilley 1975). Other than these small movements pike do not undergo extensive migrations (Tripp *et al.* 1981). After spawning pike disperse to large weedy back eddies and mouths of tributaries that have a high abundance of forage fish or to areas up to 93 km away from the spawning area that consist of small back eddies or river mouths to feed (Stein *et al.* 1973; Jessop and Lilley 1975). Adults are typically found in shallow portions of rivers, with no velocity, over

mud and silt, with aquatic vegetation used as cover (Ford *et al.* 1991). Important feeding areas in the Rabbitskin River consist of the river estuary and deep pools during July, August and September (Jessop *et al.* 1973). Catches of pike were highest in shallow, weedy areas and slow water (back eddies, river mouths, pools) (Hatfield *et al.* 1972; Stein *et al.* 1973; Jessop and Lilley 1975; Inskip 1982). In the Great Bear River pike were caught in shallow, turbid water (McCart 1982). Pike may return to the same stream to spawn every year (Jessop and Lilley 1975). Northern pike are strictly freshwater fish but can be caught sparingly in freshened areas of Wood Bay (Bond and Erickson 1991, 1992) and can also be found in the Mackenzie Delta and immediate coastal areas where salinity is low (Percy 1975).

Northern pike females can mature as early as age 1 but most do not mature until age 3 and all are mature by age 8. Males are mature between 2-6 years of age (Miller and Kennedy 1948; Cheney 1971; Jessop *et al.* 1973; Scott and Crossman 1973; Stein *et al.* 1973; De Graaf and Machniak 1977; Tripp *et al.* 1981; Chang-Kue *et al.* 1982). In northern locations pike can live to be 15-26 years of age (Miller and Kennedy 1948; Cheney 1971; Hatfield *et al.* 1972; Jessop *et al.* 1973; Stein *et al.* 1973; Falk and Dahlke 1975; De Graaf and Machniak 1977; Tripp *et al.* 1981).

Minnows (Cyprinidae)

Lake chub (*Couesius plumbeus* (Agassiz 1850))

The lake chub has the most wide-spread northern distribution of all the North American cyprinids (McPhail and Lindsey 1970). It is found in both the NT and NU (Scott and Crossman 1973), ranging in the NU from Chesterfield Inlet tributaries, Thelon, Dubawnt, and Kazin rivers and Nueltin Lake westward to the NT. In the NT it is common throughout the Mackenzie River system (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980). Lake chub prefer lakes, especially in the southern areas of their distribution, when they are available but are found frequently in rivers and streams in the northern areas. Lake chub inhabit a variety of habitats ranging from outlets of hot springs to cool northern rivers (McPhail and Lindsey 1970; Scott and Crossman 1973). Lake chub exhibit lacustrine, adfluvial and riverine life history types (Brown *et al.* 1970; Scott and Crossman 1973; Stein *et al.* 1973). Spawning occurs in lakes along shore or in streams (Scott and Crossman 1973; Lee *et al.* 1980). Lake chub are found in both clear and muddy waters and sometimes in large schools (McPhail and Lindsey 1970). For information on lacustrine habitat requirements for the lake chub please refer to Richardson *et al.* (2001). There have not been many studies conducted on the lake chub, especially in the Arctic regions, and more research is needed (Brown 1969; Scott and Crossman 1973).

Ecoregion – The lake chub is found in the Upper and Lower Mackenzie, North and East Arctic ecoregions.

Lake chub spawning has been observed in the Root and Nahanni rivers, NT during May (Stein *et al.* 1973). In the Mackenzie Delta lake chub in spawning condition were caught

during the beginning of August (Scott and Crossman 1973; De Graaf and Machniak 1977). Spawning occurs in southern Yukon in late May (McPhail and Lindsey 1970). In northern Alberta lake chub probably spawn in late May or early June (Bond and Machniak 1979). In the Montreal River in northern Saskatchewan, adfluvial lake chub have been observed spawning amongst and underneath large rocks in shallow areas (5 cm) with slow water flow during middle or late May at a temperature of 4-8°C. No nest was constructed and there is no parental care involved. Spawning in the Montreal River was also observed over silt, gravel and leaves. Both males and females arrive on the spawning grounds at the same time, and most spawning occurs during the afternoon hours (Brown 1969; Brown *et al.* 1970; McPhail and Lindsey 1970; Becker 1983). The eggs are non-adhesive (Brown *et al.* 1970; Becker 1983). It is assumed that riverine populations of lake chub spawn in similar habitats as adfluvial lake chub.

Eggs incubated at temperatures between 8-19°C hatched after ten days (Brown 1969; Brown *et al.* 1970). Adfluvial fry were first caught in the Montreal River during the first week of June and followed the current into the lake shortly after hatching. Fry were taken in the river in water less than 5 cm deep amongst submerged vegetation away from the main current. Fry were also taken at the river mouth in water 46 cm deep. Lake chub nursery areas were found at many locations in the Mackenzie River (Stein *et al.* 1973). Riverine juveniles prefer areas in creeks with rocky bottoms (Brown 1969; Brown *et al.* 1970).

After spawning in rivers, adfluvial lake chub return to the lake and remain there until it is time to spawn again (Brown 1969). Riverine adults are abundant in a variety of habitats ranging from clear streams and tributary mouths to turbid waters of the Peel, Arctic Red, Liard and Mackenzie rivers (Hatfield *et al.* 1972). Lake chub adults prefer areas in creeks with rocky bottoms (Brown 1969; Brown *et al.* 1970). In Wisconsin lake chub are commonly found in the mouths of streams at depths of 1 m or less amongst large boulders (Becker 1983). Lake chub use rocks as cover (Brown *et al.* 1970). In central British Columbia lake chub matured in their third or fourth year and lived up to five years. The same was recorded of the lake chub in Montreal River, SK, Muskeg Creek, AB and in Ten Mile Lake, NF (Brown *et al.* 1970; Scott and Crossman 1973; Bruce and Parsons 1976; Bond and Machniak 1979; Lee *et al.* 1980). Lake chub are sparingly caught in Wood Bay, NT in the freshened areas of the coastal waters (Bond and Erickson 1991).

Pearl dace (*Margariscus margarita* (Cope 1867))

The northern limit of the distribution of the pearl dace is reached in the NT. It is found in the Lower Sass and Slave river drainages of the southern NT. It has not been reported in NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). It is common in small slow headwater streams, creeks, cool bogs, lakes, and ponds (Scott and Crossman 1973; Lee *et al.* 1980; Tallman 1980). They have been taken in both clear and muddy water (McPhail and Lindsey 1970) and may exhibit both a riverine and lacustrine life history (Becker 1983). Both stream and lake spawning occurs (Tallman *et al.* 1984; Langlois 1929).

Ecoregion – The pearl dace is found in the Upper Mackenzie ecoregion only.

Little study of the pearl dace in the northern or other regions of its distribution has been done (Scott and Crossman 1973). The following information is from areas outside the NT and NU.

Pearl dace spawn in early spring after ice out (Tallman *et al.* 1984). Spawning in Michigan occurs in mid-June, in clear water, with water temperatures around 17.2-18.3°C, water depths of 50-60 cm with sand or gravel bottom. Current varied from strong to almost none. Males defend an area of stream bottom approximately 20 cm across. Males chase away other males, but drive females to the spawning area. No nest is constructed, the male simply presses the posterior of the female towards the bottom with his caudal fin and raises her head with his pectoral fin. The spawning act lasts approximately two seconds with a few eggs released. The female will usually spawn with more than one male (Langlois 1929; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). In Wisconsin spawning occurs in late March to late April or later (Becker 1983).

It is not known how long the eggs need to be incubated before hatching. In Manitoba during May through September YOY pearl dace occupy shallow pools (<50 cm deep, <5 cm/s) and shallow channels (<50 cm deep and 5-45 cm/s). Age 1 fish are abundant in shallow pools (<50 cm deep, <5 cm/s) and deep channels (>50 cm deep and 5-45 cm/s). By the fall all the fish have moved into deep pools for overwintering (Tallman and Gee 1982).

Adult pearl dace in Wisconsin are commonly found in water less than 50 cm deep and rarely in water over 1.5 m deep. They prefer substrates of sand, gravel and silt, and are less commonly found in mud, and rubble, and rarely over detritus, boulders, bedrock, and clay. There is usually sparse vegetation in the area (Becker 1983). In Manitoba age 2+ fish occupied deep channels (>50 cm deep and 5-45 cm/s) and deep pools (>50 cm deep and <5 cm/s) during May to September and moved into deep pools for overwintering (Tallman and Gee 1982). Sexual maturity is reached at age 1-2 for both males and females. It is possible that males may die after spawning. Females may grow to be age four (Scott and Crossman 1973; Tallman 1980; Becker 1983; Tallman *et al.* 1984). In Nebraska pearl dace live up to age four (Stasiak 1978) but in northern waters few fish live past age three (Tallman 1980). Many more pearl dace live to age four in lakes than in streams (Tallman *et al.* 1984).

Emerald shiner (*Notropis atherinoides* (Rafinesque 1818)

The emerald shiner has not been reported to occur in NU but is found in the Mackenzie River system from the confluence of the Great Bear River south to the rivers of Great Slave Lake (Yellowknife, Slave, Buffalo) in the NT (Rawson 1951; McPhail and Lindsey 1970; Scott and Crossman 1973). It is a pelagic species that inhabits both clear water lakes and rivers (Dymond 1926; McPhail and Lindsey 1970; Scott and Crossman 1973;

Tripp *et al.* 1981; Becker 1983). It is primarily lacustrine but riverine and adfluvial life history types likely exist (Scott and Crossman 1973; Becker 1983; Lee *et al.* 1980; Becker 1983). Very little information regarding the biology of the emerald shiner in northern Canada is available (Scott and Crossman 1973). Most information concerns lacustrine populations; there is virtually no information on riverine or adfluvial populations. For information concerning lacustrine habitat requirements refer to Richardson *et al.* (2001).

Ecoregion – The emerald shiner is found in the Lower and Upper Mackenzie ecoregions.

In Wisconsin spawning occurs as early as May and extends to early August, with the majority of spawning occurring in June and July (Becker 1983). The spawning substrate is gravel shoals, although rounded boulders, coarse rubble and sand (Campbell and MacCrimmon 1970), and hard sand or mud swept clean of detritus (Flittner 1964) are also used. Spawning occurs at night (Becker 1983).

Fertilized non-adhesive eggs sink to the bottom and hatch rapidly in just 24-32 hours (Becker 1983). Emerald shiners (YOY, juveniles and adults) are a schooling species remaining in pelagic areas of rivers for the summer near the surface, moving inshore in autumn, and finally move into deeper water to overwinter (Scott and Crossman 1973). In rivers the emerald shiner is most frequently caught in water 0.6-1.5 m deep over sand, gravel, and mud and occasionally over silt, rubble, clay and boulders. It favors pool-like conditions compared to riffle areas of streams. Vegetation does not seem to be an important habitat requirement (Becker 1983), but Tripp *et al.* (1981) recorded finding the greatest numbers of emerald shiners in vegetated areas of rivers in the NT. Adults rarely live past age three (Scott and Crossman 1973).

Spottail shiner (*Notropis hudsonius* (Clinton 1824))

The spottail shiner is not recorded to occur in the NU but is found in the NT in the Mackenzie River system downstream to the edge of the delta (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980). It is typically found in larger rivers and lakes, often being the most abundant minnow in northern areas (McPhail and Lindsey 1970; Scott and Crossman 1973; Becker 1983). It occupies water of varying clarity and sometimes forms large schools (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Lee *et al.* 1980; Becker 1983). Spottail shiners exhibit both a riverine and lacustrine life history (Wells and House 1974; Mansfield 1984). For information concerning the lacustrine habitat requirements refer to Richardson *et al.* (2001). There is little information about spottail shiner biology in the NT, most of the information below is from other areas of its distribution.

Ecoregion – The spottail shiner is found in the Lower and Upper Mackenzie ecoregions.

The time of spawning in the NT is not known. Spawning occurs during spring and early summer throughout the rest of Canada, the precise date depending on latitude and seasonal weather (Scott and Crossman 1973). In other regions (northern United States) the spottail shiner spawns in late June and early July over sandy shoals. In Wisconsin

spawning occurs in late May and early June but can occur as late as August. Spawning occurs in closely packed groups or massed aggregations over gravel in riffle areas of rivers, in water 45 cm deep, with a moderate current (Becker 1983). Spawning in a tributary stream of Lake Michigan occurred when water temperatures reached 18°C. Eggs are demersal and adhesive (Mansfield 1984). No nest is constructed (McPhail and Lindsey 1970; Becker 1983).There is no parental care of the eggs or of the young (McPhail and Lindsey 1970; Scott and Crossman 1973).

The length of the incubation period of the eggs is not known. Young and adult fish are found in the quiet water of river sloughs and in water with moderate currents, at depths ranging from 0.1-1.5 m, over substrates of sand, gravel, mud and silt, and occasionally over rubble, hardpan, bedrock, boulders, clay and detritus. They are also found in or near areas with sparse to moderate vegetation (submergent and emergent) (Becker 1983).

Spawning fish are usually three years or older, but some mature as early as age 1. Age of maturity varies but length at time of maturity is usually 65-66 mm. Spottail shiners live to be 4-5 years old in the southern area of distribution (McPhail and Lindsey 1970; Wells and House 1974; Becker 1983).

Northern redbelly dace (*Phoxinus eos* (Cope 1868))

In the NT the northern redbelly dace is found in the Peace-Mackenzie drainage basin and reaches the northern portion of its distribution at the mouth of the Arctic Red River. It is absent from NU (McPhail and Lindsey 1970; Stein *et al.* 1973; Lee *et al.* 1980). It is commonly found in quiet pool-like expansions of streams as well as boggy lakes, beaver ponds and small lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; Becker 1983). Water is either clear, stained the colour of tea or slightly turbid where northern redbelly dace are found (Becker 1983). The species exhibits both riverine and lacustrine life history types (Cooper 1935; McPhail and Lindsey 1970; Scott and Crossman 1973). For information on lacustrine life history requirements refer to Richardson *et al.* (2001). Very little study of the northern redbelly dace has occurred in the NT or NU, most information below is from other areas of its distribution.

Ecoregion – The northern redbelly dace is found in the Lower and Upper Mackenzie ecoregions.

The northern redbelly dace commences spawning in spring or early summer depending on local environmental conditions and latitude (Scott and Crossman 1973). In Bluefish Creek, NT a spawning northern redbelly dace was caught at the end of July (Hatfield *et al.* 1972). In northern Alberta spawning occurred from mid-June to the end of July at temperatures between 13.0 and 18.0°C (Das and Nelson 1990). In more southern areas (Michigan and Ontario) spawning occurs from May to late August (Cooper 1935; Hubbs and Cooper 1936; McPhail and Lindsey 1970; Becker 1983; Powles *et al.* 1992). The female attracts one to eight males, then she dashes several feet through the water being pursued by the males, and then dives headlong into a mass of filamentous algae. A few non-adhesive eggs are fertilized and scattered amongst the filaments. The group of

spawning fish then continues on to another mass of algae, depositing eggs as they go (Cooper 1935; Hubbs and Cooper 1936; McPhail and Lindsey 1970; Becker 1983). Evidence suggests that the northern redbelly dace may be a fractional spawner in some areas (Powles *et al.* 1992).

The eggs incubate from eight to ten days at temperatures from 21.1 to 26.7°C (Cooper 1935; Hubbs and Cooper 1936; McPhail and Lindsey 1970). Young and adults are found in waters 10-50 cm deep (less commonly in water 60-150 cm deep) over sand, gravel, silt and detritus (less commonly over mud, boulders, rubble, and clay) (Scott and Crossman 1973; Becker 1983). Most northern redbelly dace in Canada reach age five with a maximum age of eight years (Scott and Crossman 1973). Maturity is reached at age two and fish seldom live past three years in Michigan (Cooper 1935; Hubbs and Cooper 1936; McPhail and Lindsey 1970).

Finescale dace (*Phoxinus neogaeus* (Cope 1869))

The finescale dace is found in the Mackenzie River system downstream to the Arctic Circle within the NT but has not been recorded in the NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). It is a schooling fish found in clear stained boggy waters, including bog ponds, streams and larger lakes (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983). It exhibits both lacustrine and riverine life history types (Stasiak 1978; Das and Nelson 1990). Very little is known of the biology of the finescale dace (McPhail and Lindsey 1970; Stasiak 1978). For a summary of lacustrine habitat requirements refer to Richardson *et al.* (2001). All information below comes from areas outside the NT and NU.

Ecoregion – The finescale dace is found in the Upper and Lower Mackenzie ecoregions.

Spawning in Canada occurs in June and July (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Das and Nelson 1990). In Wisconsin spawning occurs from April to June (Becker 1983) and in Minnesota the breeding season extends from late April to May. Water temperatures in Minnesota during spawning ranged from 11-19°C and the depth of spawning was 50-90 cm. Females leave the spawning school in a zig-zag motion and are chased into areas of cover by several males. Eggs (20-30) are deposited under submerged logs and brush piles where they sink to the bottom into mud or gravel. No nests are built and no parental care is given (Stasiak 1978).

The eggs hatch four days after fertilization (Becker 1983). Finescale dace are captured in pool areas of a creek with a fine silt covered bottom and fallen spruce trees provided cover (Stasiak 1978). It is also commonly found in depths of 10-50 cm over substrates of sand, gravel, silt and mud, less common over detritus, boulders, rubble and clay (Becker 1983). Both males and females mature at age 1-2. Males can reach the age 5, while females can live to age 5 or 6. (Stasiak 1978).

Fathead minnow (*Pimephales promelas* (Rafinesque 1820))

The fathead minnow is found in the very south central portion of NT in the southern drainage of Great Slave Lake and has not been reported to occur in NU. The habitat that it occupies varies throughout its range. It can be found in still-water ponds, muddy streams, mud-bottomed lakes, muddy ditches and warm brooks (McPhail and Lindsey 1970; Scott and Crossman 1973). They exhibit both lacustrine and riverine life history types (Wynne-Edwards 1932; Scott and Crossman 1973). For information on the lacustrine habitat requirements of the fathead minnow refer to Richardson *et al.* (2001). Little information is available for the northern and riverine populations of the fathead minnow. The majority of the information below is from other areas of its distribution and spawning habitat in rivers is assumed to be similar to that described in lakes and ponds.

Ecoregion – The fathead minnow only occurs in the Upper Mackenzie ecoregion.

The fathead minnow is a fractional spawner with a prolonged spawning period occurring from April to mid-August (McPhail and Lindsey 1970; Lee *et al.* 1980; Gale and Buynak 1982; Becker 1983). Still or slightly flowing areas of streams are used for spawning with water temperatures ranging from 15.8-17.8°C. The adhesive eggs are deposited on the underside of lily pads, boards, submerged logs, and rock crevices, on either horizontal or vertical surfaces and are guarded by the male. The male tends the eggs in the nest, driving off other fish, and may spawn with one or more females (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). It is thought that males die 30 days and females 60 days after spawning (Dobie *et al.* 1956).

Eggs hatch in 4.5-6 days at 25°C but the incubation time is dependent on water temperature (Scott and Crossman 1973). After hatching the young remain near the nest until the yolk sac has been absorbed. After becoming free swimming growth is very quick, with fathead minnows in southern areas reaching adult size before their first winter (Becker 1983). They are tolerant of high water temperatures, low dissolved oxygen and turbidity (Lee *et al.* 1980). They are commonly taken in Wisconsin in water up to 1.5 m deep, with substrates consisting of sand, rubble, gravel, silt and mud and occasionally over boulders, clay, detritus, bedrock, and marl. Submerged rooted aquatic plants may also be present, but floating and submerged algae are common (Becker 1983). Maturity is reached during their second year (Lee *et al.* 1980) and they may live up to age three, but seldom survive beyond age two (Scott and Crossman 1973).

Flathead chub (*Platygobio gracilis* (Richardson 1836))

The flathead chub occurs in Great Slave Lake (including Slave River), along the Mackenzie River, north to the Mackenzie Delta in the NT, but is absent in the NU (Rawson 1951; McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Tripp *et al.* 1981). It is adapted for life in swift muddy rivers, often found in sluggish creeks and is seldom found in still or clear waters (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Tripp *et al.* 1981). Most flathead chub are found in riverine environments but one instance of a lacustrine life history type has been recorded (McPhail and Lindsey 1970; Scott and Crossman 1973; Prouse and Derksen 1974). There

have been few studies undertaken on the flathead chub, thus life history information is extremely limited.

Ecoregion - The flathead chub occurs in the Lower and Upper Mackenzie ecoregions.

Spawning occurs in the spring and early summer during late June to early August (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Stein *et al.* 1973; Tripp *et al.* 1981). They may move into small streams to spawn (Hatfield *et al.* 1972; Stein *et al.* 1973; Scott and Crossman 1973). No information was found on flathead chub spawning, YOY, juvenile or adult habitat.

Mature adults range in age from 4-13 in the Mackenzie River area (Stein *et al.* 1973). The same age range was seen in the Slave River by Tripp *et al.* (1981). Females mature before males with both spawning every year (Tripp *et al.* 1981).

Longnose dace (*Rhinichthys cataractae* (Valenciennes 1842))

The longnose dace is absent from the NU but occurs in the NT. It occurs throughout the Mackenzie River system north almost to the Arctic Circle (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980). It is characteristically found in clear or muddy swift flowing streams with gravel or boulders along the bottom, it may even inhabit very turbulent waters. It can also be found in clear pools of rivers (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983). Longnose dace may also occur in lakes (Gee and Machniak 1972; Scott and Crossman 1973; Lee *et al.* 1980). They exhibit riverine and possibly lacustrine life history types (Gee and Machnaik 1972; Scott and Crossman 1973; Hubert and Rahel 1989). They are solitary fish and do not school (McPhail and Lindsey 1970). Very little information on the longnose dace exists for northern populations, thus most of the information below is from more southern areas of its range.

Ecoregion – Longnose dace are found in the Lower Mackenzie ecoregion.

Spawning can begin in May, June or early July and may continue into late August (McPhail and Lindsey 1970; Scott and Crossman 1973; Becker 1983). Spawning occurs in riffle areas of rivers over a gravel bottom (Scott and Crossman 1973). Eggs are laid in a group amongst stones and are most likely guarded by one parent (McPhail and Lindsey 1970). In Manitoba spawning occurs in shallow streams, with a current of 45-50 cm/s and substrate material ranging in diameter from 5-20 cm, with the males defending a territory prior to spawning (Bartnik 1970). Spawning in New York state occurred in water 5-10 cm deep over an area of fine gravel. A school of 25 fish, mostly males, swim over the area, a female stops on the bottom and is surrounded by approximately six males, and spawning occurred (Bishop 1933 as cited in Becker 1983).

Eggs are adhesive and hatch in 7-10 days at 15.6°C (McPhail and Lindsey 1970). Newly hatched fish live on their yolk sac for the next seven days. They then rise to the surface, fill their swim bladder and live pelagically for about four months, living in still, shallow

water at the river margin. After four months they begin to choose faster and deeper water and eventually become bottom-dwellers (McPhail and Lindsey 1970; Scott and Crossman 1973). Juveniles, in Michigan, are found in water depths of 10-19 cm and avoid depths below 20 cm. Juveniles also avoid water velocities less than 10 cm/s and select areas with velocities of 25-50 cm/s and prefer boulders as substrate (Mullen and Burton 1995, 1998).

The longnose dace is a bottom dweller and as an adult occupies rocky sections of tributaries (Stein *et al.* 1973; Tripp *et al.* 1981). Out migrations, presumably after spawning, have been recorded from the Rabbitskin River between July 30 and September 10 into the Mackenzie River system (Jessop *et al.* 1973). In Michigan adult longnose dace use areas with faster current (25-50 cm/s) and boulder substrates, and select water depths between 10-30 cm (Mullen and Burton 1995, 1998). In Wisconsin the longnose dace occurs in riffle areas of streams over a bottom of boulders and gravel at depths of 10-50 cm, generally avoiding areas of pools and quiet runs. It prefers rubble, sand, boulders and silt, but is occasionally found over mud, clay, bedrock and detritus (Becker 1983). In Ontario longnose dace overwinter in areas of cobble and boulders in rivers (Cunjak 1996). Longnose dace are more active at night feeding, and during the day they are usually under the shelter of stones (Culp 1989). Longnose dace mature at age 2-3 (Bartnik 1970; McPhail and Lindsey 1970; Becker 1983).

Suckers (Catostomidae)

Longnose sucker (*Catostomus catostomus* (Forster 1753))

The longnose sucker is common throughout the NT and NU but is not known to occur on any of the Arctic Islands (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). It is commonly found in rivers, lakes and streams with clear or turbid water (Harris 1962; McPhaill and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973). Longnose suckers exhibit adfluvial, riverine and lacustrine life history types (Harris 1962; Geen *et al.* 1966; Stein *et al.* 1973; Edwards 1983; Walton 1980). They spawn primarily in rivers but may spawn in the shallows of lakes (Brown and Graham 1954; Harris 1962; Geen *et al.* 1966; Galloway and Kevern 1976; Morrow 1980; Walton 1980). The longnose sucker is primarily a bottom-dwelling fish (McPhail and Lindsey 1970; Morrow 1980). For information concerning their lacustrine habitat requirements refer to Richardson *et al.* (2001).

Ecoregion – The longnose sucker is found in the Lower Mackenzie, Upper Mackenzie, North Arctic and East Arctic ecoregions.

The spawning run of longnose suckers into Mosquito creek from Great Slave Lake occurs from mid to the end of May, with the downstream run occurring from the beginning of June (Falk *et al.* 1980). Spawning runs into the Hay and Arcite Red rivers began in mid-May to mid-June when water temperatures were between 8-16°C (Harris 1962; Stein *et al.* 1973). Ripe longnose suckers were found in the Rabbitskin River between May 17 and June 18 (Jessop *et al.* 1973). Spawning in Alaskan waters also takes place in late May as

well (Sturm 1988). In the Donnelly River longnose suckers begin spawning around June 6 at a water temperature of about 16°C (Harris 1962; Tripp and McCart 1974). Spawning habitat preferred by longnose suckers contains large rocks 10-50 cm in diameter, or sand and gravel less than 1 cm diameter, depths between 15-54 cm, and velocity between 25-100 cm/s (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Walton 1980; Dion and Whoriskey 1993; Dion *et al.* 1994). In streams in British Columbia and Alaska suckers can be found spawning in strong current (Geen *et al.* 1966; Sturm 1988). Spawning occurs during the day. Females move from quiet water near shore into a group of males near the stream center. Two to four males crowd beside the female and thrash about. This act can occur many times, with the female releasing a small number of eggs each time. After spawning the sexes separate and return to their previous stream positions (Scott and Crossman 1973; Walton 1980). No nest is constructed, the milt and eggs are broadcast, and the demersal fertilized eggs settle in small numbers and adhere to gravel and other substrates (Scott and Crossman 1973; Morrow 1980; Walton 1980). Spawning runs usually precede those of the white sucker (Scott and Crossman 1973). Postspawning downstream migrations were seen in the Slave River delta during late June and early July into Great Slave Lake (Tripp *et al.* 1981).

Eggs hatch in seven days when incubated at a water temperature of 17°C (Sturm 1988), fourteen days at 12°C (Walton 1980), in eight days at 15°C and 11 days at 10°C (Geen *et al.* 1966). The newly hatched young remain in the gravel for one to two weeks before emerging and migrating downstream (Geen *et al.* 1966; Scott and Crossman 1973; Tripp and McCart 1974; Walton 1980). During downstream migrations the YOY are most commonly found in fast-flowing water at or near the surface (Walton 1980). Fry were most abundant in the mouths of fast-flowing clear rocky streams but were also observed in shallow pools within the rapids of these streams (Hatfield *et al.* 1972). Fry moved out of tributary streams and into Great Bear River by mid-July and YOY were found along the Great Bear River during August and September (Chang-Kue and Cameraon 1980).

After spawning in the Donnelly River system adult adfluvial longnose suckers disperse into lakes and river habitats downstream of the spawning area to feed during the summer, some going as far as 60 km away (Tripp and McCart 1974). Adult longnose suckers migrated out of Wolverine Creek into the Great Bear River during June (Chang-Kue and Cameron 1980). Longnose suckers, both male and female, probably spawn every year after they mature (Tripp and McCart 1974; Percy 1975). Most longnose suckers return to the same river each year to spawn (Geen *et al.* 1966; Tripp and McCart 1974). Riverine longnose suckers remain in rivers and are usually found in areas of slow water (e.g., back eddies or river mouths) (Hatfield *et al.* 1972). Longnose suckers have been caught in the brackish waters of Wood Bay in during June, July and August, with the longnose suckers returning to Anderson River in mid-August (Bond and Erickson 1991, 1992). They are also caught in the Mackenzie Delta (Percy 1975).

Adfluvial adults in Great Slave Lake can reach ages of 13-14 years (Rawson 1951) or up to 19 years of age (Harris 1962). Riverine fish caught in the Donnelly River reach 22 years of age (Tripp and McCart 1974). Females tend to live longer and grow heavier than males, fish attaining 12-20 years of age have been caught in the Mackenzie River, delta

and its tributaries (Hatfield *et al.* 1972; Jessop *et al.* 1973; Stein *et al.* 1973). The maximum age of a fish caught in the Slave River delta was 28 years (Tripp *et al.* 1981). In Great Slave Lake maturity is reached at age seven but only fish age nine and older undergo spawning migrations (Harris 1962). Males reach maturity at age 4-9 and females later at age 6-12 (Jessop *et al.* 1973; Scott and Crossman 1973; Tripp and McCart 1974).

White sucker (*Catostomus commersoni* (Lacepede 1803))

The white sucker is found south of the treeline from Hudson Bay to Great Slave Lake in the southwestern portions of NU and NT (Scott and Crossman 1973; Lee *et al.* 1980). It is also found in the NT throughout most of the Mackenzie River system north to the delta and south to Great Slave Lake, but is absent from Great Bear Lake (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). They occur as far north in the Mackenzie River system as the Ramparts River (Stein *et al.* 1973) and the Arctic Red River (Hatfield *et al.* 1972). In Great Slave Lake the white sucker does not live in the lake proper but in the shallower and warmer bays and in the rivers tributary to the lake (Rawson 1951). They occur in freshwater rivers, streams and lakes, primarily in warm shallow environments (McPhail and Lindsey 1970; Scott and Crossman 1973). White suckers exhibit adfluvial, riverine and lacustrine life history types (Geen *et al.* 1966; Scott and Crossman 1973; Walton 1980; Tripp *et al.* 1981; Corbett and Powles 1983). They are known to spawn in both rivers and lakes, in outlets or along lake shores, but there is a preference for inlet streams (Nelson 1968; McPhail and Lindsey 1970; Curry and Spacie 1984; Corbett and Powles 1986). For information concerning lacustrine habitat requirements for the white sucker refer to Richardson *et al.* (2001).

Ecoregion –The white sucker is found in the Lower Mackenzie, Upper Mackenzie, and East Arctic ecoregions.

Ripe white suckers have been caught in the Rabbitskin River in the beginning of June (Jessop *et al.* 1973). In Alberta upstream migrations begin in May (Walton 1980). Upstream migrations into rivers in Quebec and British Columbia begin in mid-May from the lakes with water temperatures ranging from 8.5-16°C. Preferred spawning habitat consisted of large rocks, 10-50 cm in diameter, water depths ranging from 15-100 cm, and velocities of 22-100 cm/s (Geen *et al.* 1966; Nelson 1968; Scott and Crossman 1973; Bond and Machniak 1979; Walton 1980; Becker 1983; Corbett and Powles 1983; Dion and Whoriskey 1993; Dion *et al.* 1994). Male white suckers arrive 2-3 days before the females on the spawning grounds and are more numerous. No nests are constructed and no territories are defended (Becker 1983). A female moves into the rapids and rests on the bottom. She is approached by one to ten males. Spawning usually occurs between one female and two males, one on each side. Males spread their pectoral fins under the female and press their caudal fins against hers. The males arch their backs and spread their dorsal fins, then all three fish vibrate rapidly. Females will spawn more than once with different males (Scott and Crossman 1973; Becker 1983). The eggs are demersal and adhesive and stick to the substrate and become partially covered by bottom materials. There is no parental care given to the eggs or young (Scott and Crossman 1973; Becker 1983). Adults home to certain spawning streams. Most spawning occurs at night, but some can occur

during the day (Geen *et al.* 1966; Scott and Crossman 1973; Bond and Machniak 1979; Corbett and Powles 1983). White suckers can spawn every year but some are known to miss up to three years (Geen *et al.* 1966).

Incubation of the eggs takes 15 days at 10.0°C (Walton 1980) and in 8-11 days at water temperatures between 10-15°C (Geen *et al.* 1966; Scott and Crossman 1973). After hatching the larvae remain in the gravel for 11 days, after which they emerge and drift downstream. They are most numerous near the surface and in fast water with movement downstream primarily at night (Geen *et al.* 1966; Walton 1980; Becker 1983; Corbett and Powles 1983). White sucker fry were found in the mouths of relatively shallow, fast-flowing streams, containing some gravel (Hatfield *et al.* 1972). They spend time feeding near the surface, until their mouths become more ventral and they begin to seek food on the bottom (Becker 1983). Young white suckers are gregarious and during their first year may form schools of a few to several hundred in water 15-20 cm deep along the shore (Becker 1983). They are commonly caught in small back eddies near the stream shore (Bond and Machniak 1979).

Adfluvial white sucker adults return to the lake 10-14 days after spawning (Scott and Crossman 1973). Riverine adults are found in clear to slightly turbid water, at depths up to 1.5 m, over gravel, sand, silt, rubble, and mud substrates. There is usually sparse vegetation in the area. White suckers are less common over boulders, clay, detritus, and bedrock. The largest white suckers are found in deep holes (Becker 1983). Overwintering can occur in tributary steams for younger fish, but older fish tend to overwinter in lakes (Bond and Machniak 1979).

Adults in the Great Slave Lake area reach a maximum age of 12 years (Rawson 1951). Ages of white suckers from the Mackenzie River (Norman Wells area) ranged from 0-11+ years (Hatfield *et al.* 1972). Age-at-first maturity varies from age 5-8 (Scott and Crossman 1973) but can occur as early as age three (Ontario and Northern Alberta) (Bond and Machniak 1979; Corbett and Powles 1983). White suckers migrating into streams varied in age from 3-16 years in a northern Alberta stream, with the earliest age of maturity being age four for males and females (Bond and Machniak 1979).

Cod (Gadidae)

Burbot (*Lota lota* (Linnaeus 1758))

The burbot occurs throughout the continental portions of the NT and NU, exclusive of the northernmost areas, and is reported to be absent from the Arctic Islands (McPhail and Lindsey 1970: Scott and Crossman 1973; Lee *et al.* 1980; Tripp *et al.* 1981). It is usually found in deepwater lakes but may be found in rivers, small streams and low lying ponds (McPhail and Lindsey 1970; Scott and Crossman 1973). Burbot exhibit both lacustrine and riverine life history types in NT and NU but can also be found in brackish waters (Rawson 1951; Scott and Crosman 1973; Stein *et al.* 1973; Hunter 1975; Johnson 1975; Percy 1975; Lee *et al.* 1980; Morrow 1980; Bond 1982; Hopky and Ratynski 1983; Bond and Erickson 1991). Adfluvial migratory portions of the population have also been

documented. These burbot migrate from lakes into rivers to spawn (Burmakin and Tyurin 1959; Muller 1971; Muss and Dahlstrom 1971; Sorokin 1971; Ford *et al.* 1995; McPhail 1997). They are primarily a benthic, nocturnal fish (spawning, feeding, and general movements) (Scott and Crossman 1973; Hunter 1975; Percy 1975; Lee *et al.* 1980; Morrow 1980; Bond 1982; Hopky and Ratynski 1983; Bond and Erickson 1991). Little direct information on riverine and adfluvial populations for northern Canada was found thus most of the information below is from other regions of the burbot's distribution. For information concerning the lacustrine habitat requirements of the burbot refer to Richardson *et al.* (2001).

Ecoregions – Burbot are found in Lower Mackenzie, Upper Mackenzie, East Arctic and North Arctic ecoregions.

Burbot spawn during the winter months (January to March) under the ice or in areas where the river remains open (Sorokin 1971; McPhail and Lindsey 1970; Scott and Crossman 1973). In the Slave River there is a major migration of burbot during the late fall (November), and spawning probably occurs between late December and mid-January (McLeod 1985). In Russia burbot migrate into the tributaries of river to spawn in September when water temperatures fall to 10-12°C; this early migration is for general feeding and includes many immature fish. In October-February mature fish move upstream beyond the feeding area to spawn, with most spawning occurring in January, but it can extend into March (Sorokin 1971). Burbot lay their eggs over large cobblestones, boulders and gravel with a small amount of silt, sand and detritus, in areas with no current, with clear water and temperatures of 0-1.7°C, and in water depths of 1-1.5 m (Chen 1969; McPhail and Lindsey 1970; Sorokin 1971; Hatfield *et al.* 1972; Scott and Crossman 1973; Breeser *et al.* 1988; McPhail 1997). The actual act of spawning is said to take place in a writhing ball of intertwined burbot (2-12 fish) approximately 60 cm in diameter, which moves over the bottom (Scott and Crossman 1973). After spawning females move downstream to the lower reaches of the river first, followed by the males a few days later. There is no nest built and parents do not care for the eggs or the young (Scott and Crossman 1973). The eggs are not adhesive and are washed downstream with the spring runoff at which time they hatch (Sorokin 1971). Fluvial burbot may undergo migrations as long as 125 km to reach their spawning sites (Breeser *et al.* 1988).

Eggs incubate upwards of three months (Sorokin 1971), but hatching can occur in 30 days at temperatures of 6.1°C (Scott and Crossman 1973). By their first autumn YOY can be found under stones in streams (Muss and Dahlstrom 1968). Young-of-the-year and yearling burbot in the north are frequently found along rocky shores and sometimes in weedy areas of tributary streams. Both YOY and juveniles use weed beds, rocks, debris, and cutbanks during the day as shelter (Scott and Crossman 1973). Young-of-the-year burbot are common in the Slave River delta in the spring (Tripp *et al.* 1981). Juveniles are usually found over rocky or gravel bottoms along rocky shorelines. They will also utilize rocks, cobble, vegetation and logs for cover (Ford *et al.* 1995).

Some portions of the burbot populations may not spawn each year (Pulliainen and Korhonen 1993). In northern rivers adult burbot are associated with main channels and

appear to prefer turbid water, but will enter tributaries in the fall (Chen 1969; Hatfield *et al.* 1972; Sundet and Wenger 1984; Breeser *et al.* 1988). In the north summer habitat of the burbot is often in river channels associated with lakes (Scott and Crossman 1973). Burbot prefer areas of moderate to high turbidities, low velocities (under 46 cm/s), shallow depths (under 76 cm), and with rubble and cobble substrates in Alaskan rivers (Suchanek *et al.* 1984). They utilize the turbidity of the water they are located in as cover and are found over gravel, rock and cobble substrates (Ford *et al.* 1995)

Adults from the Mukutawa River, Manitoba reached ages of twelve years with sexual maturity occurring as early as age two (Hewson 1955). Most burbot reach sexual maturity during their third and fourth year or as late as age 6-7 in northern locations (Chen 1969; Scott and Crossman 1973; Percy 1975; Tripp *et al.* 1981; Ford *et al.* 1995). Burbot from La Grande Riviere, Quebec live to a maximum age of 12 years as well (Magnin and Fradette 1977). Scott and Crossman (1973) report the maximum age of burbot in Canada as 10-15 years of age. In northern regions burbot can attain ages as high as 14-23 years (Hatfield *et al.* 1972; Stein *et al.* 1973; Percy 1975; de Graaf and Machniak 1977; McCart *et al.* 1976; Bond 1982; Tallman *et al.* 1996).

Sticklebacks (Gasterosteidae)

Brook stickleback (*Culaea inconstans* (Kirtland 1841))

In the NT the brook stickleback is found from the Hay River region of Great Slave Lake north along the Mackenzie Valley to the Arctic Red River. It is not known to occur in the NU (Falk 1972; Hatfield *et al.* 1972; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980; Wootton 1984). The brook stickleback inhabits a wide variety of environments including spring-fed brooks and streams, trout streams, boggy lakes, and beaver ponds (McPhail and Lindsey 1970; Wootton 1976; Lee *et al.* 1980; Becker 1983; Nelson and Paetz 1992). It exhibits both riverine and lacustrine life history types (McPhail and Lindsey 1970; Foster 1971; MacLean and Gee 1971; Scott and Crossman 1973; Wootton 1976; Lee *et al.* 1980). Brook sticklebacks prefer freshwater that is cool, clear to slightly turbid and heavily weeded although they can also be found in brackish waters (Winn 1960; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983). For information concerning the lacustrine life habitat requirements of the brook stickleback refer to Richardson *et al.* (2001). Since there are no direct studies on the brook stickleback in the Canadian Arctic, all of the information below is from other areas of its distribution.

Ecoregion – The brook stickleback is found in the Lower and Upper Mackenzie ecoregions.

Spawning in the Arctic occurs during spring (Hatfield *et al.* 1972). Elsewhere, spawning occurs in May and early June in southern Manitoba and Ontario (Foster 1971; MacLean and Gee 1971). Across their whole distribution brook stickleback populations usually spawn from April to August (Reisman and Cade 1967; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983). Following the break up of winter ice brook sticklebacks move upstream from deep cold water into warm (8-19°C), shallow, meltwater ponds and ditches

with low water velocity (30 cm/s or less) to spawn. Movement usually occurs during daylight (Winn 1960; Reisman and Cade 1967; MacLean and Gee 1971; Becker 1983). All of the family Gasterosteidae has similar spawning behavior. The male defends a territory before building a nest. Once the nest is finished he entices one or more females by nipping, butting and nudging her to deposit eggs in the nest. He then fertilizes the eggs and guards them until they hatch (Reisman and Cade 1967; Winn 1960; McPhail and Lindsey 1970; Scott and Crossman 1973; McKenzie 1974; Lee *et al.* 1980; Wootton 1984). The male brook stickleback provides parental care for the eggs after spawning has occurred. They aerate the developing embryos by fanning a current of water over the eggs (McKenzie 1974). The nest is usually situated among weeds at a distance of about 8-30 cm above the substrate, it is spherical in shape with a definite entrance and no well-defined exit until the female creates one after depositing her eggs (Winn 1960; McKenzie 1969; McPhail and Lindsey 1970; Becker 1983). It is made of organic debris, algae, plant material, sticks and other material. Males secret a whitish fluid from the kidneys to cement the nest together. The stream bottom in the vicinity of the nests usually consists of organic debris and sand (Winn 1960; Reisman and Cade 1967; McPhail and Lindsey 1970; Becker 1983). For successful spawning to occur the brook stickleback requires water temperatures between 15-19°C, vegetation for nest construction, and clear water for courtship displays (Winn 1960).

Eggs are demersal and adhesive (Winn 1960). Time to hatching of the eggs is dependent on water temperature. At 10°C the eggs need twelve days to hatch, at 16-17°C they need 8-10 days, at 17-18°C they need 9-11 days and at 22°C they require four days to hatch (Winn 1960; McKenzie 1974). Once the fry emerge they remain in the area of the nest, that the male has now pulled apart (upper portion) into a loose network of material, until they become free swimming two days later. At this point the male discontinues any parental behaviour (McKenzie 1974). No information concerning juvenile habitat requirements was found.

After spawning the adult brook sticklebacks move back downstream into deeper, cooler waters for the rest of the summer (Winn 1960; Lamsa 1963). In Ontario these runs were recorded during the beginning and middle of June (Lamsa 1963) and in Michigan during early April to the end of May (Applegate 1961). Brook sticklebacks are almost always associated with dense aquatic vegetation and in these areas can be found in large aggregations swimming or remaining motionless (McPhail and Lindsey 1970). In Paint Creek, Michigan, adult brook sticklebacks have been observed burrowing in the sand and silt along the margins of the creek (10-50 cm of water, velocity of 2.54 cm/s, clear water, 3.3-8.9°C) to hide when frightened and to feed (Degraeve 1970). In a small creek in Michigan brook sticklebacks were found in areas of leaves, sticks, higher aquatic plants and algae over a silt bottom (Winn 1960). Brook sticklebacks are most common over substrates of sand, gravel, silt and mud, and less occasionally over rubble, boulders, clay, detritus and bedrock. They are common in water depths up to 1.5 m (Becker 1983). In the Mackenzie River near the Arctic Red River two brook sticklebacks were caught in turbid backwater areas, in water temperatures of 5°C, with a sand-silt bottom and void of aquatic vegetation (Falk 1972). Sexual maturity is thought to be attained by age 1 (Jacobs 1948; Winn 1960; Becker 1983) and brook sticklebacks may live to be age 3 (Becker 1983).

Threespine stickleback (*Gasterosteus aculeatus* (Linnaeus 1758))

The threespine stickleback is found in NU but is absent from the NT. In NU they are found in the western Hudson Bay region north to the Maguse River, as well as on Baffin and Devon islands (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Morrow 1980; Scott and Scott 1988; Stewart and Bernier 1988). It inhabits both freshwater and marine environments in lakes, ponds, lowland streams, and sheltered coastal bays in areas of emergent or submerged, rooted vegetation (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Scott and Scott 1988; Wootton 1976, 1984; Copp *et al.* 1998). The threespine stickleback exhibits riverine, lacustrine and anadromous life history types (Scott and Crossman 1973; Wootton 1984; Nelson and Paetz 1992). Different plate morphs also exist in areas of the distribution (Stewart and Bernier 1988). The anadromous form is referred to as trachurus (high plate count), while the freshwater form is referred to as leiurus (low plate count) (Wootton 1976). Much variation occurs among different populations which could suggest different subspecies, a single adaptive species, or that various degrees of speciation has occurred. Adequate analysis has not been possible and authorities are divided in their opinions (Hagen and McPhail 1970; Scott and Crossman 1973; Lee *et al.* 1980; Morrow 1980; Mori 1990; Larson and McIntire 1993; Cresko and Baker 1996). Below is a summary of threespine stickleback (*Gasterosteus aculeatus* complex) life history and riverine habitat requirements. For information concerning lacustrine habitat requirements refer to Richardson *et al.* (2001).

Ecoregion – The threespine stickleback is found in the East Arctic and Eastern Arctic Islands ecoregions.

Riverine

Threespine sticklebacks in the central Baffin Island region spawn in freshwater during late July and early August (Stewart and Bernier 1988). In Alaska spawning occurs in June and July with some extending as late as August (Morrow 1980). In general spawning takes place from April to September (Scott and Crossman 1973; Wootton 1976; Scott and Scott 1988; Virgl and McPhail 1994). All of the family Gasterosteidae has similar spawning behavior. The male defends a territory before building a nest. Once the nest is finished he entices one or more females to deposit eggs in the nest. He then fertilizes the eggs and guards them until they hatch (Scott and Crossman 1973; Wootton 1976; McKenzie 1974; Morrow 1980; Scott and Scott 1988). The male builds a nest using grains of sand and bits of vegetation that he cements together with a glue that he secrets from his kidney. The tubular nest has an exit and an entrance. Males will spawn with one or more females. The eggs are sticky and adhere to one another (Scott and Crossman 1973; Wootton 1976; Morrow 1980; Scott and Scott 1988). In splash pools along the west coast of British Columbia sticklebacks constructed nests in rock crevices, among low tufts of algae and on the bottom on patches of silt (Black and Wootton 1970). In Washington State low-plate number phenotypes of threespine stickleback prefer to spawn in areas with concealment (Hagen 1967; Kynard 1979). In Japanese Rivers threespine

sticklebacks construct nests over mud and sand substrates (gravel, pebble and boulder were used sparingly), at depths of 10-40 cm (up to 86 cm), in water velocities less than 20 cm/s, and at temperatures of 14 to 16°C (Mori 1994).

Eggs incubate in Alaskan waters up to fourteen days at temperatures between 9 to 16°C (Morrow 1980) and in other areas can take seven days at a temperature of 19°C (Breder and Rosen 1966). The young remain in the nest until the yolk sac is absorbed, about eight days, at which time they begin to emerge from the nest. The male chases them, captures them in his mouth and spits them back into the nest. Once they are free swimming they school around the male for a few days and then disperse (Morrow 1980). When they disperse they join schools of other young sticklebacks (Wootton 1976). No information concerning juvenile habitat requirements was found.

During the summer threespine sticklebacks on Baffin Island inhabit shallow streams where they are protected from predation by rocks and vegetation. Once winter arrives they move back into deeper areas of lakes to overwinter (Stewart and Bernier 1988). They then move into shallows again in early spring (Morrow 1980). These migrations are typical of the freshwater form of the threespine stickleback. They move from shallow water in the summer to deeper water in the winter (Scott and Scott 1988). Outside of the breeding season threespine sticklebacks remain in loosely associated schools (Wootton 1976). In splash pools along the west coast of British Columbia sticklebacks were found in water 0.5-1.5 m deep in areas of boulders and rocks with extensive algal growths (Black and Wootton 1970). In the UK threespine sticklebacks are commonly found in rivers in null to weak current, at depths of 10-100 cm, with bottom substrates from mud and clay, sand, organic debris, to gravel and emergent and submergent vegetation (Copp *et al.* 1998). The normal life span of the threespine stickleback varies between one to three years (Morrow 1980; Scott and Scott 1988). In Greenland most fish complete their life cycle in two years (Bergersen 1996) and in Alaska most live to two and a half years (Greenbank and Nelson 1958). Sexual maturity is usually reached after the first year, but some do not mature until the second year (Morrow 1980; Scott and Scott 1988).

Anadromous

Spawning is similar to the freshwater form in time and place (McPhail 1969; Morrow 1980; Virgl and McPhail 1994). A spawning migration into freshwater areas begins in spring (May), with a reverse migration to return to the ocean in the summer autumn (Coad and Power 1973; Schmidt *et al.* 1984; Scott and Scott 1988). In British Columbia anadromous populations spawn in the Salmon River along with freshwater residents. The river is slow flowing, with a sand and mud substrate and *Elodea* is the dominant submergent macrophyte. Spawning occurs along the shoreline of the rivers (Virgl and McPhail 1994). When cover is not available the threespine stickleback will not construct a nest and forgo spawning, but when cover is present it prefers to build nests in *Enteromorpha* sp. (Cleveland 1994).

Young leave the streams and esturaries where they hatched and move into saltwater in the fall to overwinter (Coad and Power 1973; Schmidt *et al.* 1984). At first they remain close

to the coast in the seaweed but enter open sea later in the fall (Coad and Power 1973; Morrow 1980). They can move great distances, over 800 km from shore (McPhail and Lindsey 1970).

Adults remain in the marine environment until they are ready to spawn again and move into freshwater or brackish environments to do so. Anadromous threespine stickleback usually mature at age one (Morrow 1980). Anadromous threespine sticklebacks differ from freshwater forms in a number of respects. Morphologically they have more lateral plates and more gill rakers on the first arch than the freshwater form (Hagen 1967; Morrow 1980). They may also show delayed reproduction, so they are larger at first reproduction and have a larger initial clutch size than freshwater resident populations (Snyder and Dingle 1989, 1990).

Ninespine stickleback (*Pungitius pungitius* (Linnaeus 1758))

The ninespine stickleback is found throughout the NT and NU including the Mackenzie River system and delta, most rivers and lakes in north central Canada and in portions of the Arctic Islands (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Sekerak and Graves 1975; Lee *et al.* 1980; Morrow 1980; Stewart and MacDonald 1981; Stewart and Bernier 1988). They are known to inhabit slow streams as well as shallow bays in lakes, tundra ponds, in brackish pools and inshore coastal waters (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). In northern Canada it is common in sloughs and shallow shore waters (Scott and Scott 1988). It exhibits riverine, lacustrine and anadromous life history types (McPhail and Lindsey 1970; Scott and Crossman 1973; Wootton 1976, 1984; Lawrence *et al.* 1984). It is a fish most often found in cool, quiet waters in weedy areas (Becker 1983; Scott and Scott 1988). There are three forms of the ninespine stickleback, European, Bering, and Mississippi. The form that exists in the NT and the NU is the Mississippi form inland and the Bering form along the coastlines and on the Arctic Islands (Mackenzie and Keenleyside 1970; Wootton 1976). For information concerning the lake habitat requirements refer to Richardson *et al.* (2001).

Ecoregion – The ninespine stickleback is found in the Lower Mackenzie, Upper Mackenzie, Western Arctic Islands, North Arctic, Eastern Arctic Islands, and East Arctic ecoregions.

Both anadromous and riverine populations spawn in fresh or brackish water (Scott and Crossman 1973). In Quebec the ninespine stickleback spawns from May to the end of June (Worgan and FitzGerald 1981; Craig and FitzGerald 1982). In Alaskan marsh areas spawning takes place during late June and early July (Cameron *et al.* 1973). McPhail and Lindsey (1970) report spawning occuring during May to late July in the Arctic but in the Rat River spawning was recorded during the end of August (Jessop *et al.* 1973). All of the family Gasterosteidae has similar spawning behavior. The male defends a territory before building a nest. Once the nest is finished he entices one or more females to deposit eggs in the nest. He then fertilizes the eggs and guards them until they hatch (Scott and Crossman 1973; McKenzie 1974; Lee *et al.* 1980; Becker 1983). The nests are built in

shallow waters, among vegetation, about 2-20 cm above the substrate (Scott and Crossman 1973; Wootton 1976). Males use fragments of aquatic vegetation bound together with a secretion from the kidney (McKenzie and Keenleyside 1970; Scott and Crossman 1973). Successful nesting only took place over a substrate of highly organic bottom mud. Nests only had one opening and females entered head first, turned around and then deposited their eggs. Males entered after and fertilized the eggs (Griswold and Smith 1973; Becker 1983). Spawning in the Rat River occurred in clear pools, 23-46 cm deep, with a current of 5.3 cm/sec and water temperature of 14°C. The banks of the stream were steep and the bottom was all silt covered with roots, sticks and leaves that provided cover for the spawning fish. When no vegetation was growing, the ninespine sticklebacks used organic debris to construct nests (Jessop *et al.* 1973). Males will spawn with one or more females (Griswold and Smith 1973; Becker 1983). Scott and Crossman (1973) noted that males could spawn with up to seven females.

There is ecological, behavioural, and morphological differences in the breeding biology between different populations of ninespine stickleback (Foster 1977). Appropriate work has not been conducted on arctic populations, thus the following is a generalization of habitat requirements for the Mississippi form. Nesting depth is between 90-135 cm, most populations use areas with aquatic vegetations to build nests, but Mississippi populations also use rocky areas. The height of the nests on plants was from 0-4 cm above the substrate and contained two or more holes (Foster 1977).

Eggs incubate for 6-7 days at a water temperature of 15-16°C, 4-5 days at 18-19°C (Wootton 1976). Unlike the brook stickleback, the ninespine stickleback does not constuct a nursery for the fry. The male leaves the nest the way it is and ensures the fry stay in it until they are able to swim away from him (Becker 1983). Once the male can no longer keep track of the fry (about two weeks after hatching) the fry move into open water (Scott and Crossman 1973). After leaving the nest the young riverine ninespine sticklebacks congregate in shallow, sandy areas where they are unavailable to predatory fish. Anadromous populations move into brackish areas to feed and grow. No information concerning juvenile habitat preference was found.

Riverine adult ninespine sticklebacks are found at depths from 0.5 to 2.5 m, current speed less than 30 cm/s, and a substrate of mud and sand (Morgan and FitzGerald 1981). In the UK ninespine sticklebacks are commonly found in rivers in null to weak current, at depths of 10-100 cm, with bottom substrates from mud and clay, sand, organic debris, and occasionally gravel, and emergent and submergent vegetation (Copp *et al.* 1998). Ninespine sticklebacks in Quebec mature at the age of one and may breed a second time at age two (Craig and FitzGerald 1982). Males seldom live past age three, but females can live to be five years of age (Cameron *et al.* 1973; Lee *et al.* 1980; Morrow 1980;Scott and Scott 1988. In the Mackenzie Delta region stickleback were age 0-2 (De Graaf and Machniak 1977). Ninespine stickleback have been taken infrequently in coastal waters of Liverpool Bay, Mackenzie Delta, Tuktoyaktuk Harbour and the Anderson River Estuary (Percy 1975; Bond 1982; Hopky and Ratynski 1983; Bond and Erickson 1991, 1992, 1993).

Trout-Perches (Percopsidae)

Trout-perch (*Percopsis omiscomaycus* (Walbaum 1792))

The trout-perch is distributed in the NT from the headwaters of the Mackenzie River to the Mackenzie River Delta and the Tuktoyaktuk Peninsula. Its distribution reaches the most southern portions of NU. It has not been recorded on any of the Arctic Islands (McAllister 1961; McPhail and Lindsey 1970; Hatfield *et al.* 1972; Jessop 1973; Scott and Crossman 1973; Lee *et al.* 1980; Tripp *et al.* 1981). It can be found in lakes, slow-moving streams, and backwaters of large rivers (McPhail and Lindsey 1970; Hatfield *et al.* 1972; Scott and Crossman 1973; Lee *et al.* 1980). Trout-perch exhibit lacustrine, adfluvial and riverine life history types (Lawler 1954; McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983). They are more common in lacustrine environments than in rivers (Scott and Crossman 1973). Spawning takes place along shores of lakes or in shallows of slow-moving streams (Lawler 1954; Magnuson and Smith 1963; McPhail and Lindsey 1970; Scott and Crossman 1973; Becker 1983). For information concerning lacustrine life history and habitat requirements refer to Richardson *et al.* (2001). There was very little information found concerning trout-perch habitat requirements in the NT or NU. Most of the information below is from other areas of the trout-perch's distribution.

Ecoregion – Trout-perch are found in the Lower Mackenzie, Upper Mackenzie and the East Arctic ecoregions.

Both adfluvial and riverine trout-perch populations spawn in rivers. Spawning usually takes place in the spring, most often during May, with the time probably dependent on temperature (Hatfield *et al.* 1972; Scott and Crossman 1973). Hatfield *et al.* (1972) reported ripe individuals during mid-June with spawning completed by early July in the Mackenzie River. In Lake Michigan spawning occurs from late June or early July until late September (House and Wells 1973). In Lake Hemming, MB trout-perch ascend tributaries in May to spawn on silt and boulder bottoms, at temperatures of 40-50°F, in waters two feet deep (Lawler 1954) and in Ontario trout-perch have been caught in the lower reaches of streams in May (Scott and Crossman 1973). Specimens of trout-perch caught in the NT in late June were sexually mature but had not spawned, suggesting the spawning period is later in the more northerly regions (Scott and Crossman 1973). In New York the trout-perch spawns in streams with gravel or rocky bottoms (Lee *et al.* 1980). Trout-perch are random spawners and no parental care is given to the eggs or young (Becker 1983). Spawning in streams (Wisconsin) occurs near the edges of the stream in approximately 3.5 feet of water over sand and rock. The spawning run begins in May, peaks in June and July and ends before September. Two or more males cluster around one female. When she is just about to release her eggs the males press against her sides and they all may break the surface of the water at which time eggs and milt are released. The dense, sticky eggs sink and attach to the bottom (Magnuson and Smith 1963; Becker 1983). After spawning many trout-perch, both male and female, die (Becker 1983).

Eggs hatch after 6.5 days at a water temperature of 20-23°C (Magnuson and Smith 1963) and in ten days at lower water temperatures (McPhail and Lindsey 1970). Young-of-the-year and juvenile trout-perch are considered to occupy benthic habitats (Hall and Rudstam 1999). Adfluvial juveniles move into lacustrine environments after becoming large enough. They will remain in the lake until they are ready to spawn again. Riverine trout perch remain in the river. Other information concerning habitat requirements for YOY and juvenile trout-perch was not found.

After spawning the adult trout-perch either remain in the river if they are riverine, or migrate back to the lake if they are adfluvial (Scott and Crossman 1973). The trout-perch is normally found in deep water during the day and moves into shallower water at night to feed on insects and other invertebrates (Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980; Becker 1983). In Wisconsin they are most frequently found in clear to slightly turbid water, over substrates of sand, mud, gravel and boulders (Scott and Crossman 1973; Becker 1983). In lake waters trout-perch prefer water temperatures of 15-16°C during the day and disperse into waters with a temperature of 7-8°C during the evening (Brandt *et al.* 1980). Trout-perch collected in Lake Michigan ranged in age from 1-7 for males and 0-8 for females. In the Mackenzie River region trout-perch were found in clear streams and tributary mouths to turbid rivers (Hatfield *et al.* 1972). They are also found in the Slave River and its tributaries (Tripp *et al.* 1981). Males tend to mature before females. Most males are mature at age two while most female mature at age three (Magnuson and Smith 1963; House and Wells 1973). Adult adfluvial trout-perch in Lake Heming, MB ranged in age from 1-3 years of age (Lawler 1954). Riverine trout-perch in the Mackenzie River area ranged in age from 1-3 years as well (Stein *et al.* 1973).

Perches (Percidae)

Iowa darter (*Etheostoma exile* (Girard 1860))

There has not been a confirmed occurrence of Iowa darters in the NT or the NU, but they could occur in the very south central portion. An isolated population is known to exist in Pine Lake, AB forty kilometers from the border of the NT (Scott and Crossman 1973; Lee *et al.* 1980). They are typically found in rivers, fast flowing streams, as well as lakes and bog ponds (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980; Becker 1983). Iowa darters are known to exhibit both lacustrine and riverine life history types (Winn 1958; McPhail and Lindsey 1970; Scott and Crossman 1973). For information concerning the lacustrine habitat requirements of the Iowa darter refer to Richardson *et al.* (2001). All of the information below is from southern Iowa darter populations, no information concerning more northerly populations was found.

Ecoregions – The Iowa darter has not been reported to occur in any of the ecoregions but could possibly occur in the Upper Mackenzie ecoregion.

Spawning occurs in spring from late April to mid-June in the southern areas of the Iowa darter's distribution (Becker 1983) but northern populations probably spawn later (Scott and Crossman 1973). The darter moves from deeper areas of the river to shallower areas

to spawn. Males usually arrive on spawning grounds before females. A drop in water temperature can halt and even reverse migration to the spawning grounds (Winn 1958). Males establish and defend semi-circlular breeding territories along the banks of streams where the current is 0.3-0.6 m/sec. These territories include submerged fibrous roots and other vegetation, and occasionally gravel and sand (Winn 1958, Copes 1970). When females are ready to spawn they move into a male's territory. When the female comes to an abrupt stop on fibrous roots, the male positions himself above her and curves his caudal region around the female, they both vibrate and three to seven eggs are deposited along with the sperm. Eggs adhere to the roots. Females will spawn with many different males and then return to deeper water (Winn 1958). No direct care to the eggs or young is provided by either of the parents.

In laboratory conditions the eggs require 18-26 days of incubation at water temperatures between 13-16°C before hatching (Jaffa 1917). Young darters are found in vegetated pools and lateral depressions in streams (Copes 1970). No other information concerning YOY or juvenile Iowa darter habitat preferences was found.

During the non-breeding season adult Iowa darters remain in deep pools of streams (Becker 1983). Adult Iowa darters are most commonly found in clear to slightly turbid water, at depths less than 1.5 m, over substrates of sand, gravel, mud and silt, and occasionally over detritus, boulders, rubble, clay and bedrock. They are also commonly associated with submergent vegetation, filamentous algae and rooted aquatic vegetation (Scott and Crossman 1973; Becker 1983). Iowa darter are more active during the day than at night. They were found in water 0.5-1.5 m deep over sandy areas during the day. At night they hide in rock crevices, holes and in and under submerged trees (Emery 1973). When the Iowa darter is alarmed it will dart up to 60 cm and then rest on the bottom or bury into the bottom substrate (Copes 1970). Winn (1958) indicated that the Iowa darter may live to be three years of age.

Yellow perch (*Perca flavescens* (Mitchill 1814))

The yellow perch reaches as far north as Great Slave Lake in the NT and is absent from the NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). They are found in sluggish streams and rivers, as well as lakes and ponds but are rarely found in areas of strong currents (Scott and Crossman 1973). Yellow Perch are most common in clear, open water with moderate vegetation. Numbers of perch decrease with increasing turbidity (Scott and Crossman 1973; Lee *et al.* 1980). They can exhibit riverine and adfluvial life history types but are mainly a lacustrine species (Scott and Crossman 1973; Kitchell *et al.* 1977; Goodyear *et al.* 1982; Weber and Les 1982; Becker 1983; Craig 2000). Very little information on northern populations of yellow perch was found. The information below was gathered from all areas of the yellow perch's distribution. For information concerning lacustrine habitat requirements refer to Richardson *et al.* (2001).

Ecoregion – The yellow perch is found in the Upper Mackenzie ecoregion.

Yellow perch begin spawning runs into shallower, low velocity river waters or from lakes into rivers during March to June when water temperatures reach 7-13°C (Harrington 1947; Scott and Crossman 1973; Weber and Les 1982). The yellow perch spawns shortly after entering such areas from mid-March to early May in most areas but spawning may extend into July in some areas (Coots 1956; Scott and Crossman 1973; Becker 1983; Weber and Les 1982; Craig 2000). In the lower region of the Slave River, NT a mature yellow perch was caught during September (Tripp *et al.* 1981). Males move into spawning grounds first, and are followed by females. Spawning takes place at night and early morning (Scott and Crossman 1973; Becker 1983; Craig 2000). The females deposit accordion-shaped, semibouyant, egg masses on submerged branches, rooted vegetation, fallen trees, sand and fine gravel substrates. The males then swim over and fertilize the egg mass (Scott and Crossman 1973; Becker 1983; Cucin and Faber 1985). No nest is built and there is no parental care of eggs or young (Scott and Crossman 1973; Becker 1983). Water temperatures during spawning varied between 12-15°C (Cucin and Faber 1985). Spawning habitats in rivers resemble those used in littoral habitats of lakes. Yellow perch also use a wide variety of spawning habitats. In general these consist of pool and slackwater areas of rivers with moderate amounts of vegetation (Coots 1956; Kitchell *et al.* 1977). In the Mississippi River spawning occurred in water velocity less than 15 cm/sec, depth range of 15-168 cm, and substrate of mud/clay and silt (Krieger *et al.* 1983). In Oyster River, New Hampshire egg strands were found amongst branches of fallen birch trees, in water 30-122 cm deep, with the water temperature at 8.9°C, in water velocities of less than 5 cm/s (Harrington 1947). In Fox River, Wisconsin, spawning substrates utilized by yellow perch consisted of sand, gravel, mud and some rubble. Spawning took place directly in or at the edge of the current. Eggs were found at depths of 0.4-2.1 m on submerged debris and detritus as well as on submerged and emergent plants (Weber and Les 1982). The egg masses begin to fragment above a water velocity of 25 cm/s (Coots 1956). After spawning adfluvial perch move back to the lake during the fall as water levels increased and water temperatures decrease (Manion 1977) while riverine yellow perch remain in the river.

Incubation times for perch eggs range from 8-20 days (Harrington 1947; Scott and Crossman 1973; Cucin and Faber 1985; Craig 2000) and are dependent on water temperature. Hatching can take as long as 27 days at a temperature of 8.3°C (Scott and Crossman 1973). In a Wisconsin river incubation took from 11-20 days at temperatures fluctuating between 2.7-21.6°C (Weber and Les 1982). After hatching adfluvial fry move to open water during the first two months of life. Adfluvial YOY yellow perch are found in Duck Creek, ON in the lower and middle reaches during April to June (Leslie and Timmins 1998) and presumably leave the system as they were not caught from July to November. After hatching riverine fry remain in the upper 0.9-1.2 m of water for three to four weeks (Becker 1983). Riverine fry choose areas with currents less than 2.5 cm/s (Houde 1969). Fry in the Mississippi River prefer habitats with water velocities below 12 cm/sec, between depths of 30-191cm, and substrates ofsilt and sand (Krieger *et al.* 1983). Riverine fry are also swept downstream by flowing water but as they become stronger they begin to swim continuously, find areas of little flow and cease to move downstream (Craig 2000).

Juvenile habitat is similar to that of adults but they are usually found in shallower water. Juveniles in the Mississippi River prefer habitats with water velocities below 12 cm/s, depths of 61-122 cm and substrate of silt, sand and some gravel (Krieger *et al.* 1983).

Adult yellow perch are most common in open water that is clear and has moderate vegetation with a bottom of muck, sand or gravel (Scott and Crossman 1973). Adult yellow perch can be found in moderate currents (Manion 1977) but prefer sluggish or slackwater areas (Coots 1956; Kitchell *et al.* 1977). Adults in the Mississippi River prefer habitats with water velocity below 12 cm/sec, water depths from 122 – 236 cm and substrate of silt, sand and some gravel (Krieger *et al.* 1983). In Wisconsin the yellow perch is most frequently found in shallow areas of rivers with clear to slightly turbid water, and over substrates of sand, gravel, mud, and silt. Occasionally they can be found over rubble, boulders, detritus, and clay (Becker 1983). During the day yellow perch form schools, stratified by size and age, which disperse at sundown to reform again at sunrise. They are inactive at night and rest on the bottom (Scott and Crossman 1973). In Canadian and northern United States waters yellow perch females mature at ages 2-4, while males mature at ages 2-3 (Scott and Crossman 1973; Weber and Les 1982; Craig 2000). Maximum age is 9-10 years but northern populations of yellow perch grow more slowly and live longer, up to 21 years of age (Scott and Crossman 1973; Craig 2000).

Walleye (*Stizostedion vitreum* (Mitchill 1818))

In the NT the walleye is found throughout the Mackenzie River drainage from Great Slave and Great Bear lakes north to the delta of the Mackenzie River. Walleye are found in the very southwest portion of the NU (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980; Craig 2000). They occur throughout the Mackenzie River drainage but are only found in abundance in the area south of Great Bear Lake. They are restricted to freshwater and tolerate only extremely low salt concentrations (McCart and Den Beste 1979). Walleye prefer to inhabit large shallow turbid lakes but can tolerate a wide variety of environments including large, turbid or clear rivers and streams, and sometimes large clear lakes (Scott and Crossman 1973; Colby *et al.* 1979; Tripp *et al.* 1981; Becker 1983). They exhibit riverine, adfluvial and lacustrine life history types (Eschmeyer 1950; Scott and Crossman 1973; Goodyear *et al.* 1982). Lacustrine populations spawn in the lake itself or in tributary streams (Becker 1983; Ford *et al.* 1985). For information concerning lacustrine habitat requirements refer to Richardson *et al.* (2001).

Ecoregions – Walleye are found in the Upper Mackenzie and Lower Mackenzie ecoregions.

Both adfluvial and riverine populations of walleyes spawn in rivers. Spawning occurs in the spring during April to June when water temperatures reach 4.5-14°C (Eschmeyer 1950; Rawson 1957; Derksen 1967; Bidgood 1968; Jessop *et al.* 1973; Scott and Crossman 1973; Summers 1978; Colby *et al.* 1979; Bodaly 1980; Tripp *et al.* 1981; Becker 1983; Corbett and Powles 1986; Harbicht and Franzin 1988; Liaw 1991; Ford *et al.* 1995; Craig 2000). Walleye are known to spawning in Island River and Marie Creek

(Mackenzie drainage). Spawning in these two tributaries occurred after ice breakup during late May at water temperatures of 7-8°C (Stein *et al.* 1973). The spawning run in Mosquito Creek begins in mid-May and continues to mid-June with most movement occurring at night (Falk *et al.* 1980a,b). Eggs are laid over a substrate of rock, rubble, or gravel although if these are not available spawning may occur over sand or silt (Eschmeyer 1950; Scott and Crossman 1973; Tripp *et al.* 1981; Ford *et al.* 1995; Craig 2000). Walleye spawning is normally nocturnal (Ellis and Giles 1965; Scott and Crossman 1973; Corbett and Powles 1986). Males usually arrive on the spawning grounds before females (Rawson 1957; Falk *et al.* 1980b). Spawning consists of either females or males approaching one another from behind or laterally and pushing the other fish. While these actions are taking place the dorsal fins are raised and lowered by both the males and females. Courtship lasts one or two minutes ending with one or more females swimming towards the surface followed by one or more males. At the surface this group swims around vigorously releasing sperm and eggs. Both male and females will spawn many times. No territories are defined and no parental care is given to the eggs or young (Eschmeyer 1950; Ellis and Giles 1965; Scott and Crossman 1973; Becker 1983; Craig 2000). Eggs are simply broadcast over the spawning substrate and fall into cracks and crevices (Eschmeyer 1950; Scott and Crossman 1973; Colby *et al.* 1979; Becker 1983).

In other Canadian and northern United States areas of its distribution walleye prefer to spawn over a substrate of sand, gravel, cobble and rubble, but will use anything from clay to large boulders, in water depths of 0-2.4 m and a current velocity of 0-1.695 m/s (Eschmeyer 1950; Arnold 1960; Bidgood 1968; MacCrimmon and Skobe 1970; McMahon *et al.* 1984; Pitlo 1989; Liaw 1991; Ford *et al.* 1995; Lowie *et al.* 2001). The walleye remain in the stream on average for 5-6 days to spawn and then move out of the stream to surrounding channels and lakes to feed for the summer (Falk *et al.* 1980b). Walleye, once mature, spawn every year in the Slave River (Tripp *et al.* 1981). However some northern populations may not spawn every year due to unfavourable environmental conditions (Colby *et al.* 1979).

The eggs are adhesive and attach to the substrate where they will incubate (Craig 2000). At temperatures between 6-12°C incubation takes 15-34 days, while at temperatures of 12-24°C incubation only takes 4-15 days (Reighard 1890; Marshall 1977; Scott and Crossman 1973; Colby *et al.* 1979; Becker 1983; Liaw 1991). Walleye egg survival is higher on a sand-gravel-rock substrate than on a mud-detritus bottom (Johnson 1961; Corbett and Powles 1986; Auer and Auer 1990). Known nursery areas in NT are as follows, the estuary of the Rabbitskin River (Jessop *et al.* 1973), and the Mackenzie River at Norman Wells, Vermilion Creek, Slater River, Little Bear River, Trail River, Harris River, Spence River and Jean-Marie Creek (Stein *et al.* 1973). All fry are photopositive prior to reaching lengths of 25-30mm (Ford *et al.* 1995). After hatching, adfluvial fry migrate passively downstream into the adjoining lake carried by the flowing water, usually during the evening hours (Becker 1983; Corbett and Powles 1986; Franzin and Harbicht 1992; Jude 1992; Johnston *et al.* 1995; Mitro and Parrish 1997; Craig 2000). They will remain in the lake until they become mature and migrate into the river to spawn. Riverine fry are also swept downstream by flowing water but as they become

stronger they begin to swim continuously, find areas of little flow and cease to move downstream (Corbett and Powles 1986; Craig 2000). Fry prefer habitats in which the water velocity is below 0.08 cm/sec, depth of 0.30-1.52 m and substrate of mud, silt, sand and gravel (McMahon *et al.* 1984). Juveniles prefer habitats where the water velocity is below 30 cm/sec, depth between 0.91-2.13 m and a substrate of sand (McMahon *et al.* 1984; Ford *et al.* 1995). Juveniles will utilize turbidity, dark waters, logs and river banks as cover (Ford *et al.* 1995). Immature walleye use the Hay River in the summer months for feeding (Roberge and Low 1987).

After spawning riverine adults move downstream or into larger tributaries, while adfluvial adults return to the main lake (Rawson 1957; Bidgood 1968; Scott and Crossman 1973; Bodaly 1980). Riverine adults feed in the Rabbitskin River estuary and move out of the Rabbitskin River in September (Jessop *et al* 1973). There is a downstream migration of adfluvial walleye in the Slave River beginning in late August and continuing until freeze-up and maybe later (Tripp *et al.* 1981). Most walleye, in northern rivers, are caught in the mouths of relatively fast-flowing, rocky streams, having low turbidity levels (Hatfield *et al.* 1972). Adult walleye, like juveniles, are photosensitive and use turbidity, boulders, submerged logs, dark water, thick layers of ice, brush, river banks and submerged vegetation as cover (Scott and Crossman 1973; Ryder 1977; McMahon *et al.* 1984; Ford *et al.* 1995). Adults prefer areas where the water velocity is below 30 cm/s, depth is greater than 122 cm and are most common over substrates of sand, gravel, mud, cobble, rubble, boulders, clay, silt and detritus in decreasing order of occurrence (Becker 1983; McMahon *et al.* 1984; Ford *et al.* 1995).

Walleye in more northern regions tend to live longer, grow larger, and mature later than walleye found in southern areas of North America (Craig 2000). Walleye in the area of the Slave River Delta ranged in ages from 0-18 years of age (Tripp *et al.* 1981). Scott and Crossman (1973 report the maximum age of walleye to be twenty years, but Falk *et al.* (1980) record a dorsal spine aged at twenty-four years from a Mosquito Creek walleye. Maturity of females ranges from age two in the south to age ten in the NT (Scott and Crossman 1973; Colby *et al.* 1979; Craig 2000). Females in the Slave River mature at age nine, with all being mature at age thirteen. Males mature earlier at age six, with all reaching maturity by age nine (Tripp *et al.* 1981). In the Hay River the youngest spent male was seven years old and the youngest spent female was ten years old (Bond *et al.* 1978). In Mosquito Creek spawning males ranged from 6-15 years of age and spawning females from 7-15 (Bond *et al.* 1978; Falk *et al.* 1980a).

Sculpins (Cottidae)

Slimy sculpin (*Cottus cognatus* (Richardson 1836))

The slimy sculpin is present throughout the NT and NU, except for the Arctic Islands (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980; Tripp *et al.* 1981). They are occasionally found in lakes but more typically found in cool, clear or muddy waters of rivers, streams and creeks with rocky or gravelly bottoms (McPhail and Lindsey 1970; Scott and Crossman 1973; Lee *et al.* 1980). The slimy

sculpin exhibits both lacustrine and riverine life history types (McPhail and Lindsey 1970; Scott and Crossman 1973; Craig and Wells 1976; Hughes and Peden 1984). For information concerning the lacustrine habitat requirements of the slimy sculpin refer to Richardson *et al.* (2001). Since few studies have been conducted in the arctic regions of North Amercia most of the information below is from more southerly areas.

Ecoregion – The slimy sculpin is found in the Lower Mackenzie, Upper Mackenzie, North Arctic and East Arctic ecoregions.

In Alaskan streams spawning occurs during late May and early June with water temperature at 3.5°C (Craig and Wells 1975). Spawning is thought to occur in the St. Charles Creek, Mackenzie River drainage but the time at which it takes place is not known (Stein *et al.* 1973). In Montreal River spawning occurred during early May at 8°C (Scott and Crossman 1973; Lee *et al.* 1980). The male selects a spawning site under a rock, ledge or submerged tree root. He then courts a female who enters the nest, deposits adhesive eggs on the ceiling that the male fertilizes and then the female leaves or is driven out. The male may spawn with one or more females and guards the eggs and young. Females only mate once a season (Koster 1936; Scott and Crossman 1973; Lee *et al.* 1980). Slimy sculpins are usually monogamous but have shown polygynous behaviour in certain conditions (Mousseau and Collins 1987).

Eggs in Montreal River required four weeks to hatch at a temperature around 8°C (Scott and Crossman 1973). In Alaska fry have been found in late June in streams (Craig and Wells 1975). Koster (1936) reported that incubation takes about a month. The eggs hatch and the fry fall to the bottom of the nest where they remain until the yolk sac is absorbed (3-6 days). Then the young begin to leave the nest. St. Charles Creek, NT, is a known nursery area for slimy sculpins (Stein *et al.* 1973). In Jack's Creek, Pennsylvania YOY slimy sculpins were found under the cobble and rubble substrate, in 13.44-21.84 cm of water, with a velocity of 0.06-0.56 m/s (Gray and Stauffer 1999). Young-of-the-year in the Straight Run River were most common at depths of 5-25 cm, in water velocities below 20 cm/s, with substrates of cobble and boulder. Juvenile slimy sculpin in the same river are found in deeper water (10-30 cm), with stronger currents (5-40 cm/s), and the same substrates of cobble and boulder (Johnson *et al.* 1992).

Adult slimy sculpins have been caught in the Rabbitskin River during August through October (Jessop *et al.* 1973). The slimy sculpin prefers clear, gravelly streams in the Arctic (Tripp *et al.* 1981). In Pennsylvania adult slimy sculpins were found under the cobble and rubble substrate, in 10-30 cm of water, with a velocity of 0.04-0.46 m/s (Johnson *et al.* 1992; Gray and Stauffer 1999). In New York streams slimy sculpins are common in water velocities of 0.43-1.72 m/s, with gravel and fine-grained substrates (Baldigo and Lawrence 2001). In streams in Wisconsin the slimy sculpin is found over substrates of rubble, boulders, silt, gravel, bedrock and sand, with dense growths of aquatic plants and moderate to fast currents, at average depths of 13 cm (Becker 1983). In the Flathead River, BC, slimy sculpins are found over substates of cobble and smooth stones with little cover available except for under the stones (Huges and Penden 1984).

Sculpin have very small home ranges and do not migrate great distances (Morrow 1980; Morgan and Ringler 1992).

In Valley Creek, MN, a female was found mature at age one, with most slimy sculpins of both sexes mature by age two. Slimy sculpin in this river can reach ages of five years (Petrosky and Waters 1975). In Alaskan waters the slimy sculpin grows much slower and reaches seven years of age. They also mature later at ages three to four (Craig and Wells 1975). Slimy sculpins in the Martin River, NT range in age from 1-3 years of age (Stein *et al.* 1973).

Spoonhead sculpin (*Cottus ricei* (Nelson 1876))

The spoonhead sculpin is present in the NU and the NT. It is present throughout much of the Mackenzie River basin and the Thelon River system (Beverly and Dubawnt Lakes) (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Lee *et al.* 1980). It occurs in shallows of large muddy rivers, small swift streams and rivers, and at considerable depths in large clear lakes (Ryder *et al.* 1964; McPhail and Lindsey 1970; Dadswell 1972; Scott and Crossman 1973; Snyder and Ochman 1985; Houston 1990). It can also be found in estuarine and brackish waters (Scott and Crossman 1973). The spoonhead sculpin is known to exhibit lacustrine and riverine life histories (Delisle and Van Vliet 1968; McPhail and Lindsey 1970; Dadswell 1972). Virtually no information is available for the riverine habitat requirements of the spoonhead sculpin. For information concerning lacustrine habitat requirements refer to Richardson *et al.* (2001).

Ecoregion – The spoonhead sculpin is found in the Lower Mackenzie, Upper Mackenzie and East Arctic ecoregions.

The spoonhead sculpin is considered to be a late summer or autumn spawner (Delisle and Van Vliet 1968; Scott and Crossman 1973), although observations in the Eastmain River, PQ suggest that they spawn during mid to late spring (Snyder and Ochman 1985). A confirmed spawning area is St. Charles Creek, NT (Stein *et al.* 1973).

No information was found concerning YOY or juvenile spoonhead sculpins. St. Charles Creek, NT is a known nursery area for spoonhead sculpins (Stein *et al.* 1973). Young are commonly found along the shallows of turbid rivers (McPhail and Lindsey 1970).

Spoonhead sculpins in the north prefer large turbid rivers (Tripp *et al.* 1981). They have been caught in the the Rabbitskin River in September (Jessop *et al.* 1973). Adults are usually found in deeper turbid water than juveniles (McPhail and Lindsey 1970).

SUMMARY AND RECOMMENDATIONS

From the summaries above is is very obvious that there is a significant lack of information on specific riverine habitat requirements of freshwater fish in the NT and the NU. This trend was also report by Richadson *et al.* (2001) in regards to lacustrine freshwater habitat in the NT and NU. Knowledge is lacking in the distribution, life history

traits, and habitat requirements. There has been much study in the Mackenzie River drainage, in relation to oil and gas resource development, but other areas of the Canadian Arctic have been neglected. With development continuing in the years to come much research is needed to fill the gap of fish habitat requirements in relation to a species life history to ensure adequate knowledge is available for management decisions. It is hoped that in the interim the information presented in this report will serve as a reference for identifying essential freshwater fish habitat in the Northwest Territories and Nunavut.

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Figure 1. Major ecoregions in Nunavut and the Northwest Territories. North Arctic region does not include any islands, only the main land. East Arctic includes all the islands of Hudson Bay, Hudson Strait and Ungava Bay.

Table 1. List of fish species occurring (x) in freshwaters riverine, anadromous and adfluvial life histories) the Northwest Territories and Nunavut.

Common Name	Scientific Name	Northwest Territories	Nunavut
Lampreys	**Petromyzontidae**		
Arctic lamprey	*Lampetra camtschatica* (Martens, 1868)	X	-
Trouts	**Salmonidae**		
lake cisco	*Coregonus artedi* (Lesueur, 1818)	X	X
Arctic cisco	*Coregonus autumnalis* (Pallas, 1776)	X	X
lake whitefish	*Coregonus clupeaformis* (Mitchill, 1818)	X	X
broad whitefish	*Coregonus nasus* (Pallas, 1776)	X	X
least cisco	*Coregonus sardinella* Valenciennes, 1848	X	X
pink salmon	*Oncorhynchus gorbushca* (Walbaum, 1792)	X	-
chum salmon	*Oncorhynchus keta* (Walbaum, 1792)	X	-
kokanee salmon (sockeye)	*Oncorhynchus nerka* (Walbaum, 1792)	X	X
chinook salmon	*Oncorhynchus tshawytsha* (Walbaum, 1792)	X	X
round whitefish	*Prosopium cylindraceum* (Pallas, 1784)	X	X
mountain whitefish	*Prosopium williamsoni* (Girard, 1856)	X	-
Arctic char	*Salvelinus alpinus* (Linnaeus, 1758)	X	X
bull trout	*Salvelinus confluentus* (Suckley, 1859)	X	
Dolly Varden	*Salvelinus malma* (Walbaum, 1792)	X	-
lake trout	*Salvelinus namaycush* (Walbaum 1792)	X	X
inconnu	*Stenodus leucichthys* (Güldenstadt, 1772)	X	-
Arctic grayling	*Thymallus arcticus* (Pallas, 1776)	X	X
Smelts	**Osmeridae**		
pond smelt	*Hypomesus olidus* (Pallas, 1814)	X	X
rainbow smelt	*Osmerus mordax* (Mitchill, 1846)	X	-
Mooneyes	**Hiodontidae**		
goldeye	*Hiodon alosoides* (Rafinesque, 1819)	X	-
Pikes	**Ecosidae**		
northern pike	*Esox lucius* (Linnaeus, 1758)	X	X
Minnows	**Cyprinidae**		
lake chub	*Couesius plumbeus* (Agassiz, 1850)	X	X
pearl dace	*Margariscus margarita* (Cope, 1868)	X	-
emerald shiner	*Notropis atherinoides* Rafinesque, 1818	X	-
spottail shiner	*Notropis hudsonius* (Clinton, 1824)	X	-
northern redbelly dace	*Phoxinus eos* (Cope, 1862)	X	-
finescale dace	*Phoxinus neogaeus* (Cope, 1869)	X	-
fathead minnow	*Pimephales promelas* (Rafinesque, 1820)	X	-
flathead chub	*Platygobio gracilis* (Richardson, 1836)	X	-
longnose dace	*Rhinichthys cataractae* (Valenciennes,1842)	X	-
Suckers	**Catostomidae**		
longnose sucker	*Catostomus catostomus* (Forster, 1753)	X	X
white sucker	*Catostomus commersoni* (Lacepede, 1803)	X	X
Cods	**Gadidae**		
burbot	*Lota lota* (Linnaeus, 1758)	X	X
Sticklebacks	**Gasterosteidae**		
brook stickleback	*Culaea inconstans* (Kirtland, 1841)	X	-
threespine stickleback	*Gasterosteus aculeatus* Linnaeus,	-	X
ninespine stickleback	*Pungitius pungitius* (Linnaeus,	X	X
Trout-perches	**Percopsidae**		
trout-perch	*Percopsis omiscomaycus* (Walbaum, 1792)	X	X
Perches	**Percidae**		
Iowa darter	*Etheostoma exile* (Girard, 1860)	X	-
yellow perch	*Perca flavescens* (Mitchill, 1814)	X	-
walleye	*Stizostedion vitreum* (Mitchill, 1818)	X	-
Sculpins	**Cottidae**		
slimy sculpin	*Cottus cognatus* (Richardson, 1836)	X	X
spoonhead sculpin	*Cottus ricei* (Nelson, 1876)	X	X

Table 2. The occurrence, riverine and anadromous freshwater fish species within the freshwater ecoregions of the Northwest Territories and Nunavut. Riverine life history indicated characters, anadromous life history by normal characters and both anadromous and riverine by underlined

Upper Mackenzie		Lower Mackenzie		North Arctic	
PETROMYZONTIDAE	LAMPREYS	PETROMYZONTIDAE	LAMPREYS	PETROMYZONTIDAE	LAMPREYS
Lampetra camtschatica	Arctic lamprey	*Lampetra camtschatica*	Arctic lamprey	*Lampetra camtschatica*	Arctic lamprey
		Lethenteron alaskense	**darktail lamprey**		
SALMONIDAE	SALMONIDS	SALMONIDAE	SALMONIDS	SALMONIDAE	SALMONIDS
Coregonus artedi	lake cisco	*Coregonus artedi*	lake cisco	*Coregonus artedi*	lake cisco
Coregonus clupeaformis	lake whitefish	*Coregonus autumnalis*	Arctic cisco	*Coregonus autumnalis*	Arctic cisco
Oncorhynchus keta	chum salmon	*Coregonus sardinella*	least cisco	*Coregonus sardinella*	least cisco
Prosopium cylindraceum	**round whitefish**	*Coregonus clupeaformis*	lake whitefish	*Coregonus clupeaformis*	lake whitefish
Salvelinus alpinus	Arctic char	*Coregonus nasus*	broad whitefish	*Coregonus nasus*	broad whitefish
Salvelinus namaycush	**lake trout**	*Oncorhynchus gorbuscha*	pink salmon	***Prosopium cylindraceum***	**round whitefish**
Stenodus leucichthys	inconnu	*Oncorhynchus keta*	chum salmon	*Salvelinus alpinus*	Arctic char
Thymallus arcticus	**Arctic grayling**	*Oncorhynchus nerka*	kokanee salmon	***Salvelinus namaycush***	**lake trout**
		Oncorhynchus tshawytscha	chinook salmon	*Stenodus leucichthys*	inconnu
		Prosopium cylindraceum	**round whitefish**	***Thymallus arcticus***	**Arctic grayling**
		Prosopium williamsoni	mountain whitefish		
		Salvelinus alpinus	Arctic char		
		Salvelinus confluentus	**bull trout**		
		Salvelinus malma	Dolly Varden		
		Salvelinus namaycush	**lake trout**		
		Stenodus leucichthys	inconnu		
		Thymallus arcticus	**Arctic grayling**		
		OSMERIDAE	SMELTS	OSMERIDAE	SMELTS
		Hypomesus olidus	**pond smelt**	*Osmerus mordax*	rainbow smelt
		Osmerus mordax	rainbow smelt		
HIODONTIDAE	MOONEYES	HIODONTIDAE	MOONEYES		
Hiodon alosoides	**goldeye**	***Hiodon alosoides***	**goldeye**		
ESOCIDAE	PIKES	ESOCIDAE	PIKES	ESOCIDAE	PIKES
Esox lucius	**northern pike**	***Esox lucius***	**northern pike**	***Esox lucius***	**northern pike**
CYPRINIDAE	MINNOWS	CYPRINIDAE	MINNOWS	CYPRINIDAE	MINNOWS
Couesius plumbeus	**lake chub**	***Couesius plumbeus***	**lake chub**	***Couesius plumbeus***	**lake chub**
Margariscus margarita	**pearl dace**	***Mylocheilus caurinus***	**peamouth**		
Notropis atherinoides	**emerald shiner**	***Notropis atherinoides***	**emerald shiner**		
Notropis hudsonius	**spottail shiner**	***Notropis hudsonius***	**spottail shiner**		
Phoxinus eos	**northern redbelly dace**	***Phoxinus neogaeus***	**finescale dace**		
Phoxinus neogaeus	**finescale dace**	***Platygobio gracilis***	**flathead chub**		
Pimephales promelas	**fathead minnow**	***Rhinichthys cataractae***	**longnose dace**		
Platygobio gracilis	**flathead chub**				
CATOSTOMIDAE	SUCKERS	CATOSTOMIDAE	SUCKERS	CATOSTOMIDAE	SUCKERS
Catostomus catostomus	**longnose sucker**	***Catostomus catostomus***	**longnose sucker**	***Catostomus catostomus***	**longnose sucker**
Catostomus commersoni	**white sucker**	***Catostomus commersoni***	**white sucker**		
GADIDAE	CODS	GADIDAE	CODS	GADIDAE	CODS
Lota lota	**burbot**	***Lota lota***	**burbot**	***Lota lota***	**burbot**
GASTEROSTEIDAE	STICKLEBACKS	GASTEROSTEIDAE	STICKLEBACKS	GASTEROSTEIDAE	STICKLEBACKS
Culaea inconstans	**brook stickleback**	***Culaea inconstans***	**brook stickleback**	***Pungitius pungitius***	**ninespine stickleback**
Pungitius pungitius	**ninespine stickleback**	***Pungitius pungitius***	**ninespine stickleback**		
PERCOPSIDAE	TROUT-PERCH	PERCOPSIDAE	TROUT-PERCH	PERCOPSIDAE	TROUT-PERCH
Percopsis omiscomaycus	**trout-perch**	***Percopsis omiscomaycus***	**trout-perch**	***Percopsis omiscomaycus***	**trout-perch**
PERCIDAE	PERCHES	PERCIDAE	PERCHES		
Etheostoma exile	**Iowa darter**	***Perca flavescens***	**yellow perch**		
Perca flavescens	**yellow perch**	***Stizostedion vitreum***	**walleye**		
Stizostedion vitreum	**walleye**				
COTTIDAE	SCULPINS	COTTIDAE	SCULPINS	COTTIDAE	SCULPINS
Cottus cognatus	slimy sculpin	*Cottus cognatus*	slimy sculpin	*Cottus cognatus*	slimy sculpin
Cottus ricei	**spoonhead sculpin**	***Cottus ricei***	**spoonhead sculpin**		

Table 2 cont. The occurrence riverine and anadromous freshwater fish species within the freshwater ecoregions of the Northwest Territories and Nunavut. Riverine life history indicated characters, anadromous life history by normal characters and both anadromous and riverine by underlined

East Arctic		Western Arctic Islands		Eastern Arctic Islands	
SALMONIDAE	SALMONIDS	SALMONIDAE	SALMONIDS	SALMONIDAE	SALMONIDS
Coregonus artedi	lake cisco	*Coregonus autumnalis*	Arctic cisco	*Coregonus sardinella*	least cisco
Coregonus clupeaformis	lake whitefish	*Coregonus sardinella*	least cisco	*Salvelinus alpinus*	Arctic char
Prosopium cylindraceum	**round whitefish**	*Coregonus clupeaformis*	lake whitefish		
Salvelinus alpinus	Arctic char	*Salvelinus alpinus*	Arctic char		
Salvelinus namaycush	**lake trout**	***Salvelinus namaycush***	**lake trout**		
Thymallus arcticus	**Arctic grayling**				
ESOCIDAE	PIKES				
Esox lucius	**northern pike**				
CYPRINIDAE	MINNOWS				
Couesius plumbeus	**lake chub**				
CATOSTOMIDAE	SUCKERS				
Catostomus catostomus	**longnose sucker**				
Catostomus commersoni	**white sucker**				
GADIDAE	CODS				
Lota lota	**burbot**				
GASTEROSTEIDAE	STICKLEBACKS	GASTEROSTEIDAE	STICKLEBACKS	GASTEROSTEIDAE	STICKLEBACKS
Gasterosteus aculeatus	threespine stickleback	***Pungitius pungitius***	**ninespine stickleback**	*Gasterosteus aculeatus*	threespine stickleback
Pungitius pungitius	**ninespine stickleback**			***Pungitius pungitius***	**ninespine stickleback**
PERCOPSIDAE	TROUT-PERCH				
Percopsis omiscomaycus	**trout-perch**				
COTTIDAE	SCULPINS				
Cottus cognatus	slimy sculpin				
Cottus ricei	**spoonhead sculpin**				

Table 3. Riverine habitat requirement data for the Arctic lamprey.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H	H	H		301	296, 860	296, 860	
21-60 cm								
60-100 cm								
100-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	H	L	L		296, 860, 301	296, 860	296, 860	
Sand	H	L	L		301, 860, 297	296, 860	296, 860	
Silt/Clay		H	H			296, 860	296, 860	
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)		H	H			296, 860	296, 860	
Other								
Flow:								
Pool	H	H	H		301	296, 860	296, 860	
Run								
Riffle								
Rapid								
Water quality:								
Clear	L				296			
Turbid	H	H	H		296	296	296	

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Water temperature at spawning time is 12.2-15.0°C (301, 860, 297).

Adults die after spawning (860, 296).

Larvae found in eddies and backwaters of rivers with silty mud bottom where they burrow (860, 296).

Table 4. Riverine habitat requirement data for the anadromous Arctic cisco.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	M				638			
21-60 cm	M				638			
60-100 cm								
100-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	H				636, 637, 638			
Sand								
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool								
Run	M				636, 637, 638			
Riffle	M				636, 637, 638			
Rapid								
Water quality:								
Clear	M				638			
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Arctic cisco are only found in rivers during spawning migrations and spawning.

Adults, young and juveniles spend the rest of their life in brackish or estuarine areas of the coast.

Adults can tolerate turbid water but prefer less turbid waters for spawning (638; 437; 636).

Table 5. Riverine habitat requirement data for the anadromous lake whitefish.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm								
60-100 cm	H			H	844			658
100-200 cm	H			H	844			658
>200 cm	H			H	844			658
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	H				844			
Sand	H				844			
Silt/Clay	L				422			
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool								
Run	H				844			
Riffle	H				844			
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in late September to early October (653) at temperatures of 1.0 to 1.5°C (653, 658).

Adult lake whitefish mature between 7-13 years of age (653, 422, 656, 670, 329, 330, 331).

Table 6. Riverine habitat requirement data for the adfluvial lake whitefish.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	L	H			401	377		
21-60 cm	L	H			401	377		
60-100 cm	H				402			
100-200 cm	H				402, 401			
>200 cm	H				416, 401			
Substrate:								
Bedrock	L				416, 401			
Boulder	M				416, 401			
Rubble	H				381,402, 401			
Cobble	H				402			
Gravel	H				381, 402, 416, 401			
Sand	L				416, 401			
Silt/Clay	L				416, 401			
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)		H				377		
Other								
Flow:								
Pool	L				401			
Run	H				402, 401			
Riffle	H				381, 402, 401			
Rapid	H				381, 416, 401			
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Water temperatures at time of spawning range from 9.4 to a low of 0°C (660, 393, 416, 407).

Upstream migrations occur in August and September with spawning occuring in October (660).

Adfluvial lake whitefish young and juveniles leave the rivers and use the lakes as nursuries (377).

Table 7. Riverine habitat requirement data for the anadromous broad whitefish.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	M				847			
21-60 cm	M	M			847	645,419		
60-100 cm		H				645,419		
100-200 cm		M	M	M		645, 421, 419	641, 645	641, 645
>200 cm			H	H			720	720, 421
Substrate:								
Bedrock								
Boulder								
Rubble			M	M			670	670
Cobble		M	M			419	419	
Gravel	H	H	H	H	845, 657, 847	421	421	657,421
Sand	M	M	M	M	847	419	657, 670	657, 670
Silt Clay		M	M	M		419	670	670
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H	H			658, 421, 847	421		
Run		M	H	M		654, 668	421	421
Riffle			M	H			654, 668	654, 668
Rapid								
Water quality:								
Clear								
Turbid	M	M	M	M	654	654	654	654

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Not extremely tolerant of salt water compared to other coregonines (657; 437).

Gillnets caught broad whitefish at depths between 3-6 m in the Mackenzie River (720).

Spawn in back eddies of the Mackenzie river (658).

Older stages, especially adults, can tolerate turbid water conditions (654).

Table 8. Riverine habitat requirement data for the anadromous least cisco.

Habitat Features:	Ratings 1				Sources 2			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm								
21-60 cm								
60-100 cm								
100-200 cm	H				873			
>200 cm	H				873			
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	H				636, 722, 873			
Sand	H				636, 722, 873			
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool								
Run								
Riffle	H				873			
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

In Alaskan river spawning occurs at water temperatures of 0 to 3°C (873).

Spawning occurs in the months of September to October (653).

Table 9. Riverine habitat requirement data for the anadromous pink salmon.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm	H				894, 844, 584, 845, 889, 892, 891, 900, 893, 890,			
60-100 cm	M				889, 893, 890, 892, 891, 900			
100-200 cm	L				584			
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble	H				889, 898, 897			
Gravel	H				894, 844, 584, 845, 889, 898, 897			
Sand	L				889, 898, 897			
Silt/Clay	L				889, 898, 584			
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)		H				881, 844		
Other								
Flow:								
Pool	L				584			
Run	H				900, 898, 886, 889, 893, 895, 891, 892			
Riffle	H				894, 844, 584, 845, 845, 844, 900, 898, 886, 889, 893, 895, 891, 892			
Rapid	H				900, 898, 886, 889, 893, 895, 891, 892			
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High) . [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs from August to September, although no spawning populations occur in NT or NU (894, 844, 584, 845). Adults die shortly after spawning (844, 845, 584).

Table 10. Riverine habitat requirement data for the anadromous chum salmon.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H				878			
21-60 cm	H				878			
60-100 cm								
100-200 cm								
>200 cm								
Substrate:								
Bedrock	L				845, 586			
Boulder	L				845, 586			
Rubble								
Cobble	L				845, 586			
Gravel	H				845, 586			
Sand								
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents		H				585		
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)		H				882		
Other								
Flow:								
Pool	H				878, 885, 886			
Run	H				878, 885, 886			
Riffle	H				878, 885, 886			
Rapid	M				878			
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in the fall (September to November) (442, 636, 586, 660).

Both adults die shortly after spawning (semelparous) (845).

Table 11. Riverine habitat requirement data for the anadromous (sockeye) and freshwater resident (kokanee) salmon.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H				906			
21-60 cm	H				906			
60-100 cm	H				906			
100-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble	H	H			905	845		
Cobble	H	H			905, 901, 902	845		
Gravel	H	H			844, 845, 905, 901, 902	844, 845		
Sand								
Silt Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)		H				845		
Other								
Flow:								
Pool								
Run								
Riffle	H				844, 845, 905			
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs from August to September (844, 845).

They prefer to spawn in areas with ground water upwelling (906).

Adults die after they spawn (845, 844, 906).

Table 12. Riverine habitat requirement data for the anadromous chinook salmon.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm	H				911, 844, 845			
60-100 cm	H				911, 844, 845			
100-200 cm	H				911, 844, 845			
>200 cm	H				911, 844, 845			
Substrate:								
Bedrock								
Boulder			H				906, 907	
Rubble								
Cobble	H	H	H		911, 844, 845	911, 844, 845	906, 907	
Gravel	H	H			911, 844, 845	911, 844, 845		
Sand	H	H			911	906, 907		
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None			H				909	
Submergents								
Emergents		H				909		
Floating								
Flooded								
Overhead								
In Situ (Substrate)		H				911, 844, 845		
Other								
Flow:								
Pool	H	H			911	909, 906, 907		
Run	H		H		911		909, 906, 907	
Riffle	H				911			
Rapid	H				911			
Water quality:								
Clear		H	H			908	908	
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs during July to early September in the north (844, 586, 845, 908).

Subgravel flow is the most important characteristic used to choose the spawning area (911).

Females mature at 6-7 years of age, males mature at age 3-5 (844).

Table 13. Riverine habitat requirement data for the adfluvial round whitefish.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm		H	H			448, 763	448	
21-60 cm	H	H	H		763	448, 763	448	
60-100 cm	H	M		H	200, 763	763		650
100-200 cm	M	M		H	200, 763	763		650
>200 cm	M	M		H	200	763		650
Substrate:								
Bedrock								
Boulder	M			H	200, 763			763, 650
Rubble	H		M	L	678, 763		448	763
Cobble	H	L		H	763	210		763, 650
Gravel	H	L	M	L	844, 678, 200, 763	210	448	763
Sand	L	H	M		678	210, 448	448	
Silt Clay	M	H	H		678, 763	448	448	
Hard-pan								
Detritus (muck)								
Cover:								
None			H				448	
Submergents		H		M		763		763
Emergents				L				763
Floating								
Flooded								
Overhead		H		M		763		763
In Situ (Substrate)		H		H		763		763
Other								
Flow:								
Pool		H	H	H		448, 763	448	
Run	H				763			
Riffle	H			H	200, 763			763
Rapid								
Water quality:								
Clear	H				844			
Turbid		H	H	H		763	763	763

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in October and November during daylight (844, 678, 200, 763).

Temperature ranges from 0.0 to 4.5°C (845, 678, 200).

Round whitefish mature between the ages of 6-9 (208, 659).

Table 14. Riverine habitat requirement data for the adfluvial and riverine mountain whitefish.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H	H	M	M	920, 913, 661	913	661	661
21-60 cm	H		H	H	920, 913, 661		661	661
60-100 cm	H		H	H	920, 913, 661		661	661
100-200 cm	M		H	H	913		661	661
>200 cm	M		H	H	915		661	661
Substrate:								
Bedrock								
Boulder	M	H			919, 920	913		
Rubble	M	H			919, 913	919, 913		
Cobble	H	H		H	919, 920, 661,	919		661
Gravel	H	H	H	H	844, 661, 920, 913, 661	919	661	661
Sand			H				661	
Silt/Clay		M				916		
Hard-pan								
Detritus (muck)								
Cover:								
None	M	M			919	919		
Submergents			H	H			661	661
Emergents			H	H			661	661
Floating								
Flooded								
Overhead			H	H			661	661
In Situ (Substrate)								
Other								
Flow:								
Pool		H	H	M		913, 844, 915	661	915
Run				H				661
Riffle	H			H	844, 661, 919, 920, 913, 661			661
Rapid	H				920, 661			
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). 2 Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs from September through to February in some locations, but is usually completed by the beginning of November in northern rivers (913, 844, 917, 915, 920, 919, 661, 921).

They can be found in both clear and turbid streams (844).

Table 15. Riverine habitat requirement data for the riverine and stream-resident bull trout.

Habitat Features:	Ratings 1				Sources 2			
Categories 3	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	L	H			61, 68	691		
21-60 cm	M	M	H	H	61	691	691, 770, 77	770
60-100 cm	H				61			
100-200 cm	M				61			
>200 cm								
Substrate:								
Bedrock								
Boulder		H	H	M		691, 74	691, 66	91
Rubble		H		H		691		85
Cobble		H	H			691, 74, 82	691, 82, 66	
Gravel	H	H	H	H	61, 726, 107, 78	107, 82, 691	85, 691, 82	85, 82
Sand			M	H			85	85, 82
Silt Clay		M	M			691	691	
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents		H	H	M		691	691	107, 85, 91
Emergents								
Floating								
Flooded								
Overhead			H	M			770, 77, 85, 107, 81, 79, 77	85
In Situ (Substrate)		H				691		
Other								
Flow:								
Pool	H	H	H	H	726, 107, 78, 61	691, 74,	693, 691, 85, 107, 81, 77, 79	107, 770, 85
Run			H	M			691, 770, 77	82
Riffle				M				82
Rapid								
Water quality:								
Clear	H	H	H	H	726	726	726	726
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:
Water temperature at spawning is at or below 9°C (691, 726). Eggs incubate for 200-223 days (700, 66). Juveniles and YOY depend on cover more during the day than at night (79, 77).
Bull trout are usually highly associated with ground water upwelling (726, 107, 78, 61).

Table 16. Riverine habitat requirement data for the adfluvial bull trout.

Habitat Features:	Ratings 1				Sources 2			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	M	H	L		68, 102, 93, 75	695, 89	75	
21-60 cm	H	H	H		102, 68, 88, 75	68, 695	68, 75	
60-100 cm	L	L	H		68	68	68, 75	
100-200 cm		L	M			68	68	
>200 cm								
Substrate:								
Bedrock								
Boulder		M	M			68	68	
Rubble	H				64			
Cobble	H	H	H		68	68	68	
Gravel	H	H	H		68, 88, 66	68	68	
Sand		L	L			68	68	
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents		M	M			64	64	
Emergents		M	M			64	64	
Floating								
Flooded								
Overhead	M	H	H		68, 93	64	64	
In Situ (Substrate)								
Other								
Flow:								
Pool	H	M	H		93, 102, 88, 75, 68	64, 73	73, 75	
Run	H	H	M		102, 75, 68	64, 73	75	
Riffle	H	H	M		102, 31, 75	64, 73	75	
Rapid								
Water quality:								
Clear	H	H	H		726	726	726	
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:
Adults are lacustrine, except when spawning in rivers (726, 691, 66, 68, 93, 102).
Juveniles spend 1-3 years in the river before migrating to the lake to mature (66, 108, 65).
Spawning and overwintering habitat associated with regions of groundwater upwelling (683, 78).
Eggs incubate for 200-223 days (700, 66).

Table 17. Riverine habitat requirement data for the anadromous Dolly Varden.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm	H	H	H	H	370, 950	650	650	357
60-100 cm		H	H	H		650	650	357
100-200 cm				H				357
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble		M	M			650	650	
Cobble	H	M	M		370, 950	650	650	
Gravel	H	H	H	H	370, 950, 945	936, 370, 372, 406	396, 370, 372, 406	406
Sand								
Silt/Clay	H				370, 950			
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents			H					
Emergents							650	
Floating								
Flooded			H				650	
Overhead			H				650	
In Situ (Substrate)		H				936, 370, 372		
Other								
Flow:								
Pool	H	H	H	H	945	936, 370, 372, 650	936, 370, 372, 650	357
Run								
Riffle	H				370, 950			
Rapid								
Water quality:								
Clear	H	H	H	H	370	406	406	406
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in mid-August to October in the area of perennial springs in rivers (943, 936, 372, 370, 940).
Perennial spings are an extremly important rearing, overwintering and spawning habitat (357, 940, 370).

Table 18. Riverine habitat requirement data for the adfluvial lake trout.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H				793			
21-60 cm	H				793, 839			
60-100 cm	H				839			
100-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder	H				838, 839			
Rubble	H				839			
Cobble	H				793			
Gravel	H				838, 839			
Sand								
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H				838			
Run								
Riffle								
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in September and October (398, 721).

Table 19. Riverine habitat requirement data for the anadromous Arctic char.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H	H	H		844, 137, 680, 730	934, 935, 927, 152, 122	934, 935, 927, 152, 122	
21-60 cm	H	H	H		844, 137, 680, 730, 183	934, 935, 927, 152, 122	934, 935, 927, 152, 122	
60-100 cm	H	H	H		183	152	152	
100-200 cm	H				934, 935, 152, 932, 183			
>200 cm	H				934, 935, 152, 932			
Substrate:								
Bedrock								
Boulder								
Rubble	H				844, 137, 680, 730, 183, 148			
Cobble	M				183, 148			
Gravel	H	H	H		844, 137, 680, 730, 152, 183, 148	930	930	
Sand	M				152, 183			
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H	H	H		152, 148	122	122	
Run	H				152, 148			
Riffle	H				152			
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in September and October (137, 844, 680, 730, 148).

Overwintering by anadromous juveniles and adults occurs mainly in lakes (836, 176, 148, 183).

Table 20. Riverine habitat requirement data for the anadromous inconnu.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm								
60-100 cm								
100-200 cm	H				320			
>200 cm	H				320			
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	H				320			
Sand	M				320			
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool								
Run								
Riffle	H				320			
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in late September in the Anderson, Peel, and Arctic Red rivers (314, 653, 320)

Spawning habitat requirements are assumed to be similar for adfluvial inconnu.

There is virtually no information concerning YOY and juvenile inconnu habitat requirements for both anadromous and adfluvial life history types.

Table 21. Riverine habitat requirement data for the adfluvial Arctic grayling.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm	H				661			
60-100 cm	H				661			
100-200 cm	H				661			
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble	H				844, 460			
Cobble								
Gravel	H				844, 460, 956, 957, 958, 959, 463, 467, 464, 455			
Sand	M				956, 957, 958, 959, 455, 460			
Silt Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H				463, 460, 455, 467, 464			
Run	H				463, 467, 464, 455			
Riffle	H				463, 460, 455, 467, 464			
Rapid	H				463, 467, 464, 455			
Water quality:								
Clear	H				759			
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:
Spawning occurs in the spring from mid-May to early June (844, 460, 461, 449, 454, 957).

Table 22. Riverine habitat requirement data for the riverine Arctic grayling.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm	H	H	H	M	661	447, 461, 956, 781, 661	708, 705, 650, 448, 703	650, 763, 458
60-100 cm	H		H	M	661		708, 705, 650, 448, 703	650, 763, 458
100-200 cm	H			H	661			650, 763, 458
>200 cm								
Substrate:								
Bedrock								
Boulder		H	L			447, 461, 956, 781, 661	708, 705, 650, 448, 703	
Rubble	H		M	H	844, 460		708, 705, 650, 448, 703	447, 650
Cobble		H	L			447, 461, 956, 781, 661	708, 705, 650, 448, 703	
Gravel	H		H	H	844, 460, 956, 957, 958, 959, 463, 467, 464, 455		447	447, 650,
Sand	M	H	M	M	956, 957, 958, 959, 455, 460	447, 461, 956, 781, 661	447, 708, 705, 650, 448, 703	447, 650,
Silt/Clay		H	H			447, 461, 956, 781, 661	708, 705, 650, 448, 703	
Hard-pan								
Detritus (muck)								
Cover:								
None				L				650, 763, 458
Submergents			M	L			708, 705, 650, 448, 703	650, 763, 458
Emergents				L				650, 763, 458
Floating								
Flooded								
Overhead			M	M			708, 705, 650, 448, 703	650, 763, 458
In Situ (Substrate)		H	H	H		447, 661	708, 705, 650, 448, 703	650, 763, 458
Other								
Flow:								
Pool	H	H	H	M	463, 460, 455, 467, 464	447, 461, 956, 781, 661	708, 705, 650, 448, 703	650, 763, 458
Run	H	H	H	M	463, 467, 464, 455	447, 461, 956, 781, 661	708, 705, 650, 448, 703	650, 763, 458
Riffle	H	H		H	463, 460, 455, 467, 464	447, 461, 956, 781, 661		650, 763, 458
Rapid	H			H	463, 467, 464, 455			650, 763, 458
Water quality:								
Clear	H	H	H	H	759	650	650	763
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:
Spawning occurs in the spring from mid-May to early June (844, 460, 461, 449, 454, 957).

Table 23. Riverine habitat requirement data for the riverine pond smelt.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H				31			
21-60 cm	H				31			
60-100 cm	H				31			
100-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble	H				471			
Cobble								
Gravel	H				29			
Sand	H	H	H		29	471	471	
Silt/Clay		H	H			471	471	
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents	H				31			
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H				31			
Run	H				31			
Riffle	H				31			
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in June in northern Alaska (471).

Table 24. Riverine habitat requirement data for the anadromous and adfluvial rainbow smelt.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm	H				48			
60-100 cm	H				48			
100-200 cm	H				48			
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble	H				43, 56, 38, 471			
Cobble								
Gravel	H				43, 56, 38, 471			
Sand								
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents	H				43, 56, 38			
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool								
Run	H				43, 471			
Riffle	H				43, 471			
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Rainbow smelt enter the rivers during March and April with spawning occuring in April to June (422, 47, 58, 48).

Spawning occurs mostly at night and some adults die after spawning (471, 43).

Eggs hatch 10-29 days later, depending on temperature and young are swept down to the estuary or lake (471, 670, 56).

Table 25. Riverine habitat requirement data for the riverine and adfluvial goldeye.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H				387			
21-60 cm	H	H	H	H	387	288	387, 287	387, 287
60-100 cm		H	H	H		288	387, 287	387, 287
100-200 cm		H	H	H		292	387, 287	387, 287
>200 cm			H	H			387, 287	387, 287
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel	H				292			
Sand	H	M			292	288, 292		
Silt Clay		H	H	H		288	292	292
Hard-pan								
Detritus (muck)	H				292			
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H	H	H	H	387, 408	288, 292	287, 387	287, 387
Run				H				292
Riffle								
Rapid								
Water quality:								
Clear								
Turbid	H	H	H	H	287, 286, 844, 387, 848	287, 286, 844, 387, 848	287, 286, 844, 387, 848	287, 286, 844, 387, 848

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:
Spawning occurs in the spring from May to the beginning of July at night (294, 387, 285, 408).
Eggs are semibouyant and hatch after 2 weeks of incubation (287, 387, 289).
Adfluvial populations use the same spawning habitat, but YOY, juveniles and adults live in lakes and only use rivers as migration channels and spawning areas.

Table 26. Riverine habitat requirement data for the riverine and adfluvial northern pike.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H	H	H	H	963, 653, 661, 342, 349	963, 653, 661, 342, 349	340, 661	661, 863, 340, 653, 658
21-60 cm	H	H	H	H	963, 653, 661, 342, 349	963, 653, 661, 342, 349	340, 661	661, 863, 340, 653, 658
60-100 cm			H	H			340, 661	661, 863, 340, 653, 658
100-200 cm			H	H			340, 661	661, 863, 340, 653, 658
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel								
Sand								
Silt/Clay	H	H	H	H	342, 349	342, 349	661	661
Hard-pan								
Detritus (muck)	H	H			342, 349	342, 349		
Cover:								
None	L	L	L	L	355	355	355	355
Submergents	H	H	H	H	333, 863, 653, 661, 342, 349	596		653, 658, 661, 863, 340
Emergents	H	H	H	H	333, 863, 653, 661, 342, 349	596		653, 658, 661, 863, 340
Floating								
Flooded	H	H			333, 863, 653, 661	596		
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H	H	H	H	596, 661, 342, 349	679, 653	679, 653	653, 658, 661, 679
Run								
Riffle								
Rapid	L				960			
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:
Spawning occurs in the spring after ice break up during May and June in rivers and lakes (596, 661).
Water temperature during spawning is between 4-16°C (863, 653, 661).
Adfluvial habitat is the same for spawning and YOY. For lake habitats of juveniles and adults please refer to Richardson *et al* (2001).

Table 27. Riverine habitat requirement data for the adfluvial and riverine lake chub.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H	H	H	H	6, 2, 844, 782	6, 2	6, 2	782
21-60 cm		H	H	H		6, 2	6, 2	782
60-100 cm				H				782
100-200 cm				H				782
>200 cm								
Substrate:								
Bedrock								
Boulder	H	H	H	H	6, 2, 844, 782	6, 2	6, 2	6, 2, 782
Rubble	H	H	H	H	6, 2, 844, 782	6, 2	6, 2	6, 2
Cobble		H	H	H		6, 2	6, 2	6, 2
Gravel								
Sand								
Silt Clay	M				6, 2, 844, 782			
Hard-pan								
Detritus (muck)	M				6, 2, 844, 782			
Cover:								
None								
Submergents		H	H			6, 2	6, 2	
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)	H	H	H	H	6, 2, 844, 782	2	2	2
Other								
Flow:								
Pool	H	H	H	H	6, 2, 844, 782	6, 2	6, 2	6, 2
Run								
Riffle								
Rapid								
Water quality:								
Clear	M	M	M	M	844, 863	844, 863	844, 863	844, 863
Turbid	M	M	M	M	844, 863	844, 863	844, 863	844, 863

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in the spring during late May and early June, but can occur as late as August (653, 4, 656, 844, 768, 6, 2, 782).

Adfluvial habitat characteristics are described for river spawning (S and Y above), riverine habitat includes all columns (S, Y, J, and A).

Table 28. Riverine habitat requirement data for the riverine pearl dace.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H	H	H	M	20, 844, 19, 17	15	15	16, 15
21-60 cm	H	H	H	H	20, 844, 19, 17	15	15	16, 15
61-100 cm			H	H			15	16, 15
101-200 cm			H	H			15	16, 15
>200 cm								
Substrate:								
Bedrock				L				16
Boulder				L				16
Rubble				M				16
Cobble				M				16
Gravel	H	H	H	H	20, 844, 19, 17	20, 844, 19, 17	20, 844, 19, 17	16
Sand	H	H	H	H	20, 844, 19, 17	20, 844, 19, 17	20, 844, 19, 17	16
Silt/Clay				H				16
Hard-pan								
Detritus (muck)				L				16
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	M	H	H	H	20, 844, 19, 17	15	15	15
Run	M	H	H	H	20, 844, 19, 17	15	15	15
Riffle	M				20, 844, 19, 17			
Rapid	M				20, 844, 19, 17			
Water quality:								
Clear	M	M	M	M	844	844	844	844
Turbid	M	M	M	M	844	844	844	844

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in early spring, after ice out (21).

Males may die after spawning (19, 961, 16, 21).

Table 29. Riverine habitat requirement data for the emerald shiner.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm		H	H	H		275	275	275
61-100 cm		H	H	H		275	275	275
101-200 cm		H	H	H		275	275	275
>200 cm								
Substrate:								
Bedrock								
Boulder	M	M	M	M	284	275	275	275
Rubble	M	M	M	M	284	275	275	275
Cobble								
Gravel	H	H	H	H	284	275	275	275
Sand	M	H	H	H	284, 758	275	275	275
Silt Clay	M	M	M	M	758	275	275	275
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents		M	M	M		275, 676	275, 676	275, 676
Emergents		M	M	M		275, 676	275, 676	275, 676
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool		H	H	H		275	275	275
Run		H	H	H		275	275	275
Riffle		L	L	L		275	275	275
Rapid		L	L	L		275	275	275
Water quality:								
Clear	H	H	H	H	761, 844, 283, 676, 275	761, 844, 283, 676, 276	761, 844, 283, 676, 277	761, 844, 283, 676, 278
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs between May to early August (275).

Eggs hatch rapidly only needing 24-32 hrs of incubation (275).

Table 30. Riverine habitat requirement data for the spottail shiner.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H	H	H	H	7	7	7	7
21-60 cm	H	H	H	H	7	7	7	7
61-100 cm		H	H	H		7	7	7
101-200 cm		H	H	H		7	7	7
>200 cm								
Substrate:								
Bedrock		M	M	M		7	7	7
Boulder		M	M	M		7	7	7
Rubble		M	M	M		7	7	7
Cobble								
Gravel	H	H	H	H	7	7	7	7
Sand		H	H	H		7	7	7
Silt/Clay		H	H	H		7	7	7
Hard-pan		M	M	M		7	7	7
Detritus (muck)		M	M	M		7	7	7
Cover:								
None								
Submergents		M	M	M		7	7	7
Emergents		M	M	M		7	7	7
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool		H	H	H		7	7	7
Run	H	H	H	H	7	7	7	7
Riffle	H				7			
Rapid								
Water quality:								
Clear	M	M	M	M	844, 863, 8, 7	844, 863, 8, 7	844, 863, 8, 7	844, 863, 8, 7
Turbid	M	M	M	M	844, 863, 8, 7	844, 863, 8, 7	844, 863, 8, 7	844, 863, 8, 7

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs during spring and early summer when water temperatures reach 18°C (9, 12).

Spottail shiners mature after they reach 65-66 mm in length (844, 14, 7).

Table 31. Riverine habitat requirement data for the northern redbelly dace.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H	H	H	H	268, 265	268, 265	268, 265	268, 265
21-60 cm	H	H	H	H	268, 265	268, 265	268, 265	268, 265
61-100 cm		M	M	M		268, 265	268, 265	268, 265
101-200 cm		M	M	M		268, 265	268, 265	268, 265
>200 cm								
Substrate:								
Bedrock								
Boulder		M	M	M		268, 265	268, 265	268, 265
Rubble		M	M	M		268, 265	268, 265	268, 265
Cobble								
Gravel		H	H	H		268, 265	268, 265	268, 265
Sand		H	H	H		268, 265	268, 265	268, 265
Silt Clay		H	H	H		268, 265	268, 265	268, 265
Hard-pan								
Detritus (muck)		H	H	H		268, 265	268, 265	268, 265
Cover:								
None								
Submergents	H				269, 963, 844, 265			
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H	H	H	H	844, 268, 265	844, 268, 265	844, 268, 265	844, 268, 265
Run								
Riffle								
Rapid								
Water quality:								
Clear	H	H	H	H	265	265	265	265
Turbid	L	L	L	L	265	265	265	265

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning begins in spring or early summer and may continue into August (268, 269, 963, 844, 265, 270).

Evidence suggests that they may be fractional spawners (270).

Eggs incubate for 8-10 days in water 21.1-26.7°C (269, 963, 844).

Table 32. Riverine habitat requirement data for the finescale dace.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm		H	H	H		306	306	306
21-60 cm	H	H	H	H	303	306	306	306
61-100 cm	H				303			
101-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder		L	L	L		306	306	306
Rubble		L	L	L		306	306	306
Cobble								
Gravel	H	H	H	H	303	306	306	306
Sand		H	H	H		306	306	306
Silt/Clay	H	H	H	H	303	303, 306	303, 306	303, 306
Hard-pan								
Detritus (muck)		L	L	L		306	306	306
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)	H	H	H	H	303	303	303	303
Other								
Flow:								
Pool	H	H	H	H	303	303	303	303
Run								
Riffle								
Rapid								
Water quality:								
Clear	M	M	M	M	844, 305, 307, 306	844, 305, 307, 306	844, 305, 307, 306	844, 305, 307, 306
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in June and July (844, 305, 307, 267).

Eggs hatch in four days (306).

Table 33. Riverine habitat requirement data for the fathead minnow.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H	H	H	H	259	259	306	306
21-60 cm	H	H	H	H	259	259	306	306
61-100 cm			H	H			306	306
101-200 cm			H	H			306	306
>200 cm								
Substrate:								
Bedrock			L	L			264	264
Boulder			L	L			264	264
Rubble			H	H			264	264
Cobble								
Gravel			H	H			264	264
Sand			H	H			264	264
Silt Clay			H	H			264	264
Hard-pan								
Detritus (muck)			L	L			264	264
Cover:								
None								
Submergents	H	H	H	H	844, 259, 257	264	264	264
Emergents								
Floating			H	H			264	264
Flooded								
Overhead								
In Situ (Substrate)	H	H			844, 259, 257	264		
Other								
Flow:								
Pool	H	H	H	H	844, 259, 257	264	264	264
Run	H	H	H	H	844, 259, 257	264	264	264
Riffle								
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:
Fathead minnows are fractional spawners, spawning between April to mid-August (844, 257, 258, 264).
Eggs hatch in approximately 4.5-6 days and young remain near nest until the yolk sac is absorbed (259, 264).

Table 34. Riverine habitat requirement data for the flathead chub.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm								
21-60 cm								
61-100 cm								
101-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel								
Sand								
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool								
Run		H	H	H		844, 863, 23, 676	844, 863, 23, 676	844, 863, 23, 676
Riffle		H	H	H		844, 863, 23, 676	844, 863, 23, 676	844, 863, 23, 676
Rapid								
Water quality:								
Clear	L	L	L	L	844, 863, 23, 676	844, 863, 23, 676	844, 863, 23, 676	844, 863, 23, 676
Turbid	H	H	H	H	844, 863, 23, 676	844, 863, 23, 676	844, 863, 23, 676	844, 863, 23, 676

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in the spring and early summer (late June to early August) (844, 863, 23, 653, 676).

Table 35. Riverine habitat requirement data for the longnose dace.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H	H	H	H	965, 264	249, 250	249, 250	249, 250, 264
21-60 cm				H				249, 250, 264
61-100 cm								
101-200 cm								
>200 cm								
Substrate:								
Bedrock				L				264
Boulder		H	H	H		249, 250	249, 250	249, 250, 264
Rubble	H			H	965			264
Cobble	H				965			
Gravel	H			H	965, 264			264
Sand				H				264
Silt Clay				L				264
Hard-pan								
Detritus (muck)				L				264
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)		H	H	H		248	248	248
Other								
Flow:								
Pool		H	L	L		844, 254	264	264
Run	H	H	H	H	965	844, 254	249, 250	249, 250
Riffle	H		H	H	965		249, 250, 264	249, 250, 264
Rapid								
Water quality:								
Clear	M	M	M	M	844, 254, 253, 264	844, 254, 253, 264	844, 254, 253, 264	844, 254, 253, 264
Turbid	M	M	M	M	844, 254, 253, 264	844, 254, 253, 264	844, 254, 253, 264	844, 254, 253, 264

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning can begin in May, June or early July and continue to late August (844, 254, 264).

Eggs are adhesive and hatch in 7-10 days at a water temperature of 15.6°C (844).

Table 36. Riverine habitat requirement data for the riverine and adfluvial longnose suckers.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H	H			844, 863, 628, 634, 400, 631	621, 628, 449, 634		
21-60 cm	H	H			844, 863, 628, 634, 400, 631	621, 628, 449, 634		
61-100 cm								
101-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder								
Rubble	H				844, 863, 628, 634, 400, 631			
Cobble	H				844, 863, 628, 634, 400, 631			
Gravel	H	H			844, 863, 628, 634, 400, 631	621, 628, 449, 634		
Sand	H				844, 863, 628, 634, 400, 631			
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)		H				621, 628, 449, 634		
Other								
Flow:								
Pool		H	H	H		634, 863	863	863
Run	H	H	H	H	844, 863, 628, 634, 400, 631	634, 863	863	863
Riffle	H				844, 863, 628, 634, 400, 631			
Rapid	H				844, 863, 628, 634, 400, 631			
Water quality:								
Clear	M	M	M	M	630, 844, 863, 628	630, 844, 863, 628	630, 844, 863, 628	630, 844, 863, 628
Turbid	M	M	M	M	630, 844, 863, 628	630, 844, 863, 628	630, 844, 863, 628	630, 844, 863, 628

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in the spring during mid-May to mid-June (706, 630, 653, 679, 762, 449).

Eggs require 7-14 days to hatch in water 17-12°C (762, 634, 621).

Table 37. Riverine habitat requirement data for the riverine and adfluvial white sucker.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H	H	H	H	621, 620, 616, 768, 634, 782, 618, 400, 631	782	782	782
21-60 cm	H			H	621, 620, 616, 768, 634, 782, 618, 400, 631			782
61-100 cm	H			H	621, 620, 616, 768, 634, 782, 618, 400, 631			782
101-200 cm				H				782
>200 cm								
Substrate:								
Bedrock				L				782
Boulder	H			L	621, 620, 616, 768, 634, 782, 618, 400, 631			782
Rubble	H			H	621, 620, 616, 768, 634, 782, 618, 400, 631			782
Cobble	H				621, 620, 616, 768, 634, 782, 618, 400, 631			
Gravel		H		H		621, 782, 618, 634, 863		782
Sand				H				782
Silt Clay				H				782
Hard-pan								
Detritus (muck)				L				782
Cover:								
None								
Submergents				L				782
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H			H	621, 620, 616, 768, 634, 782, 618, 400, 631			782
Run	H	H		H	621, 620, 616, 768, 634, 782, 618, 400, 631	621, 782, 618, 634		782
Riffle	H	H		H	621, 620, 616, 768, 634, 782, 618, 400, 631	621, 782, 618, 634		782
Rapid	H				621, 620, 616, 768, 634, 782, 618, 400, 631			
Water quality:								
Clear	H	H	H	H	782	782	782	782
Turbid	M	M	M	M	782	782	782	782

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in May and June (679, 634, 621, 616).

Incubation of eggs requires 8-15 days at temperatures ranging from 10-15°C (634, 621, 616).

Table 38. Riverine habitat requirement data for the adfluvial and riverine burbot.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H			H	968, 844, 219, 863, 236, 969, 967			763
21-60 cm	H			H	968, 844, 219, 863, 236, 969, 967			763
61-100 cm	H			H	968, 844, 219, 863, 236, 969, 967			763
101-200 cm	H				968, 844, 219, 863, 236, 969, 967			
>200 cm								
Substrate:								
Bedrock								
Boulder	H	H	H		968, 844, 219, 863, 236, 969, 967	227, 236	236, 661	
Rubble		H	H	H		227, 236	236, 661	661
Cobble	H	H	H	H	968, 844, 219, 863, 236, 969, 967	227, 236	236, 661	661
Gravel	H	H	H	H	968, 844, 219, 863, 236, 969, 967	227, 236	236, 661	661
Sand	M				968, 844, 219, 863, 236, 969, 967			
Silt/Clay	M				968, 844, 219, 863, 236, 969, 967			
Hard-pan								
Detritus (muck)	M				968, 844, 219, 863, 236, 969, 967			
Cover:								
None								
Submergents		H	H			227, 236	236, 661	
Emergents								
Floating								
Flooded								
Overhead		H	H			236	236	
In Situ (Substrate)		H	H			227, 236	236, 661	
Other								
Flow:								
Pool	H			H	968, 844, 219, 863, 236, 969, 967			763
Run				H				763
Riffle								
Rapid								
Water quality:								
Clear	H				968, 844, 219, 863, 236, 969, 967			
Turbid		H	H	H		968, 863, 763, 969	968, 863, 763, 969	968, 863, 763, 969

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Burbot spawn during the winter months either under the ice or in areas where water remains open (219, 844, 236).

Table 39. Riverine habitat requirement data for the riverine brook stickleback.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H	H		H	972, 518, 511, 515	972, 518, 511, 515		512, 515
21-60 cm	H	H		H	972, 518, 511, 515	972, 518, 511, 515		512, 515
61-100 cm				H				515
101-200 cm				H				515
>200 cm								
Substrate:								
Bedrock				L				515
Boulder				L				515
Rubble				L				515
Cobble								
Gravel				H				515
Sand	H	H		H	972, 518, 511, 515	972, 518, 511, 515		512, 507
Silt Clay				H				512, 972, 507
Hard-pan								
Detritus (muck)	H	H		L	518, 972, 844, 515	972, 518, 511, 515		515
Cover:								
None								
Submergents	H	H	H	H	972, 516, 513, 515	972, 516, 513, 515	972, 516, 513, 515, 844	972, 516, 513, 515, 844
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H	H		H	972, 518, 511, 515	972, 518, 511, 515		512
Run	H	H		M	972, 518, 511, 515	972, 518, 511, 515		512
Riffle								
Rapid								
Water quality:								
Clear	H	H	H	H	972, 516, 513, 515	972, 516, 513, 515	972, 516, 513, 515, 512	972, 516, 513, 515, 512
Turbid	L	L	L	L	972, 516, 513, 515	972, 516, 513, 515	972, 516, 513, 515	972, 516, 513, 515, 507

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in the spring after ice has left at water temperatures of 15-19°C (863, 972).

Table 40. Riverine habitat requirement data for the anadromous and riverine threespine stickleback.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H	H		H	489	489		979
21-60 cm	H	H		H	489	489		473, 979
61-100 cm				H				473, 979
101-200 cm				H				473
>200 cm								
Substrate:								
Bedrock								
Boulder	M	M		H	489	489		473
Rubble	H	H		H	980, 488, 489			473
Cobble	M	M			489			
Gravel	M	M		H	489			979
Sand	H	H		H	980, 488, 489			979
Silt/Clay	H	H		H	980, 488, 489			979
Hard-pan								
Detritus (muck)	H	H		H	980, 488, 489			979
Cover:								
None								
Submergents	H	H		H	844, 476, 503, 505, 970, 978, 979	844, 476, 503, 505, 970, 978, 979		844, 476, 503, 505, 970, 978, 979
Emergents	H	H		H	844, 476, 503, 505, 970, 978, 979	844, 476, 503, 505, 970, 978, 979		844, 476, 503, 505, 970, 978, 979
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H	H		H	489	489		473, 979
Run								
Riffle								
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning for both forms occurs during the spring (714, 985, 845, 475).

Anadromous threespine stickleback move downstream into marine waters to overwinter during the summer that they hatch. riverine fish move into deeper freshwater areas (714, 480, 763).

Table 41. Riverine habitat requirement data for the riverine ninespine stickleback.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H	H			516, 970, 679	516, 970, 679		
21-60 cm	H	H		H	516, 970, 679	516, 970, 679		494
61-100 cm	H	H		H	496	496		494
101-200 cm	H	H		H	496	496		494
>200 cm				H				494
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble	H	H			496	496		
Gravel								
Sand		H		H		516		494
Silt Clay	H	H		H	679	679		494
Hard-pan								
Detritus (muck)	H	H			502, 499	502, 499		
Cover:								
None								
Submergents	H	H	H	H	499, 505, 516, 970, 496	499, 505	499, 505	499, 505
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)	H	H			496, 679	496, 679		
Other								
Flow:								
Pool	H	H		H	679	679		494
Run				H				494
Riffle								
Rapid								
Water quality:								
Clear								
Turbid								

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs from June to August in northern regions (506, 679, 844).

Eggs hatch in 4-7 days at temperatures from 15-19°C (970).

Table 42. Riverine habitat requirement data for the adfluvial and riverine trout-perch.

Habitat Features:	Ratings 1				Sources 2			
Categories 3	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H				523, 526			
21-60 cm	H				523, 526			
61-100 cm	H				526			
101-200 cm								
>200 cm								
Substrate:								
Bedrock								
Boulder	H			H	523			525, 782
Rubble								
Cobble	H				521, 526			
Gravel	H			H	521			525, 782
Sand	H			H	526			525, 782
Silt Clay	H			H	523			525, 782
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H			H	844, 525, 521			
Run								
Riffle								
Rapid								
Water quality:								
Clear	H	H	H	H	525, 782, 863	525, 782, 863	525, 782, 863	525, 782, 863
Turbid	M	M	M	M	525, 782, 863	525, 782, 863	525, 782, 863	525, 782, 863

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning of riverine and adfluvial populations occurs in rivers during May to September (525, 519, 523, 526).

Adfluvial trout-perch move into the lake at an early age, while riverine populations remain in the river (525).

Young-of-the-year and juveniles are considered to be benthic inhabitants (527).

Adult riverine trout-perch occupy deep waters during the day and move into shallow areas at night to feed (525, 521, 782).

Table 43. Riverine habitat requirement data for the riverine Iowa darter.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H			H	611			607, 608
21-60 cm	H			H	611			607, 608, 987
61-100 cm				H				607, 608, 987
101-200 cm				H				607, 608, 987
>200 cm								
Substrate:								
Bedrock				L				607, 608
Boulder				L				607, 608
Rubble				L				607, 608
Cobble								
Gravel	M			H	611, 986			607, 608
Sand	M			H	611, 986			607, 608, 987
Silt Clay				H				607, 608
Hard-pan								
Detritus (muck)	H			L	611, 986			607, 608
Cover:								
None								
Submergents	H	H	H	H	611, 986	986	986	607, 608
Emergents		H	H	H		986	986	607, 608
Floating								
Flooded				H				987
Overhead								
In Situ (Substrate)				H				987
Other								
Flow:								
Pool		H	H	H		986	986	607
Run	H				611, 986			
Riffle								
Rapid								
Water quality:								
Clear	H	H	H	H	607	607	607	607
Turbid	M	M	M	M	607	607	607	607

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in the spring (April to June), but probably starts later in more northerly locations (607, 608).

During the day Iowa darters are active, at night they hide in rock crevices, holes and under submerged trees (987).

Table 44. Riverine habitat requirement data for the riverine and adfluvial yellow perch.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm	H				593			
21-60 cm	H	H			593, 595, 993	593		
61-100 cm	H	H	H		593, 595, 993	782, 593	593	
101-200 cm	H	H	H	H	593, 595, 993	782, 593	593	593
>200 cm	M			H	993			593
Substrate:								
Bedrock								
Boulder				M				782
Rubble	M			M	993			782
Cobble								
Gravel	H		M	H	596, 782, 216, 993		593	596, 593, 782
Sand	H	H	H	H	596, 782, 216, 993	593	593	596, 593, 782
Silt Clay	H	H	H	H	593	593	593	593, 782
Hard-pan								
Detritus (muck)				H				596
Cover:								
None								
Submergents	H			M	596, 782, 216, 990, 594			596
Emergents	H			M	596, 782, 216, 990, 594			596
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool	H	H	H	H	595, 596, 993, 990, 594, 593	989, 593	593	990, 594, 593
Run				M				992
Riffle								
Rapid								
Water quality:								
Clear	H	H	H	H	596, 592	596, 592	596, 592	596, 592
Turbid	L	L	L	L	596, 592	596, 592	596, 592	596, 592

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Both adfluvial and riverine populations of yellow perch spawn in rivers during the spring (990, 596, 782, 993, 994). Adfluvial yellow perch leave the river just after hatching. Habitat for young, juveniles and adults above only refers to riverine yellow perch.

Table 45. Riverine habitat requirement data for the riverine and adfluvial walleye.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	S	Y	J	A	S	Y	J	A
Depth:								
0-20 cm	H				561, 999, 555, 1002, 560, 1003, 557, 661, 997			
21-60 cm	H	H			561, 999, 555, 1002, 560, 1003, 557, 661, 997	560	560, 661	
61-100 cm	H	H	H		561, 999, 555, 1002, 560, 1003, 557, 661, 997	560	560, 661	
101-200 cm	H	H	H	H	561, 999, 555, 1002, 560, 1003, 557, 661, 997	560	560, 661	560, 661, 782
>200 cm	H		H		561, 999, 555, 1002, 560, 1003, 557, 661, 997			
Substrate:								
Bedrock								
Boulder	L			L	561, 999, 555, 1002, 560, 1003, 557, 661, 997			560, 661, 782
Rubble	H			M	561, 569, 676, 661, 991, 999, 555, 1002, 560, 1003, 557, 997			560, 661, 782
Cobble	H			H	561, 999, 555, 1002, 560, 1003, 557, 997			560, 661, 782
Gravel	H	H		H	561, 569, 676, 661, 991, 999, 555, 1002, 560, 1003, 557, 997	560		560, 661, 782
Sand	M	H	H	H	561, 569, 676, 661, 991, 999, 555, 1002, 560, 1003, 557, 997	560	560, 661	560, 661, 782
Silt Clay	L	H		M	561, 569, 676, 661, 991, 999, 555, 1002, 560, 1003, 557, 997	560		560, 661, 782
Hard-pan								
Detritus (muck)				L				560, 661, 782
Cover:								
None								
Submergents			H	H			661	569, 570, 661, 560
Emergents				H				569, 570, 661, 560
Floating								
Flooded								
Overhead			H				661	
In Situ (Substrate)			H	H			661	569, 570, 661, 560
Other				H				569, 570, 661, 560
Flow:								
Pool	H	H	H	H	561, 999, 555, 1002, 560, 1003, 557, 661, 997	560	560, 661	560, 661, 782
Run	H		H	H	561, 999, 555, 1002, 560, 1003, 557, 661, 997		560, 661	560, 661, 782
Riffle	H				561, 999, 555, 1002, 560, 1003, 557, 661, 997			
Rapid	H				561, 999, 555, 1002, 560, 1003, 557, 661, 997			
Water quality:								
Clear	M	M	M	M	569, 556, 782, 676	569, 556, 782, 676	569, 556, 782, 676	569, 556, 782, 676
Turbid	H	H	H	H	569, 556, 782, 676	569, 556, 782, 676	569, 556, 782, 676	569, 556, 782, 676

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.
[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Both adfluvial and riverine walleye spawn in streams during spring after ice has left (561).

Walleye egg survival is higher on sand-gravel-rock substrate than on a mud-detritus bottom (577, 566, 994).

Fry are photopositive until they reach 25-30mm (661) at which time they become photosensitive (569, 570, 661, 560).

Table 46. Riverine habitat requirement data for the riverine slimy sculpin.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm		H	H	H		542, 1006	1006	542, 1006, 782
21-60 cm		H	H	H		542, 1006	1006	542, 1006
61-100 cm								
101-200 cm								
>200 cm								
Substrate:								
Bedrock	H			H	1005, 532			782
Boulder	H	H	H	H	1005, 532	1006	1006	782
Rubble	H	H		H	1005, 532	542		542, 1006, 782
Cobble		H	H	H		542, 1006	1006	542, 1006, 782, 546
Gravel				H				1008, 782
Sand				H				1008, 782
Silt/Clay				H				782
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents				H				782
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)	H	H	H	H	1005, 532	542, 1006	542, 1006	542, 1006, 546
Other								
Flow:								
Pool		H	H	H		542, 1006	1006	542, 1006
Run		H	H	H		542	1006	542, 1006, 782
Riffle		H		H		542		542, 1006, 1008, 782
Rapid				H				1008, 782
Water quality:								
Clear	M	M	M	M	844, 532, 535, 676	844, 532, 535, 676	844, 532, 535, 676	844, 532, 535, 676
Turbid	M	M	M	M	844, 532, 535	844, 532, 535	844, 532, 535	844, 532, 535

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Spawning occurs in late May and early June with water temperatures between 3.5-8°C (545, 532, 535).

Slimy sculpins are usually found under the substrate hiding (542, 1006).

Slimy sculpins have very small home ranges and do not migrate great distances (845, 1007).

Table 47. Riverine habitat requirement data for the the spoonhead sculpin.

Habitat Features:	Ratings [1]				Sources [2]			
Categories [3]	**S**	**Y**	**J**	**A**	**S**	**Y**	**J**	**A**
Depth:								
0-20 cm		H	H			844	844	
21-60 cm		H	H	H		844	844	844
61-100 cm				H				844
101-200 cm				H				844
>200 cm				H				844
Substrate:								
Bedrock								
Boulder								
Rubble								
Cobble								
Gravel								
Sand								
Silt/Clay								
Hard-pan								
Detritus (muck)								
Cover:								
None								
Submergents								
Emergents								
Floating								
Flooded								
Overhead								
In Situ (Substrate)								
Other								
Flow:								
Pool								
Run								
Riffle								
Rapid								
Water quality:								
Clear			L	L			844	844
Turbid			H	H			844	844

[1] Ratings are - (no information), L (Low), M (Medium) and H (High). [2] Sources are numbered and listed in the back of the manuscript.

[3] Categories are S (Spawning), Y (Young-of-the-year), J (Juveniles), A (Adults).

Comments and Observations:

Exact time of spawning is not known. It may occur in spring or late summer and autumn (550, 549, 552).

Reference List for Tables

Numbers below correspond to the numbered references found in tables 3-47. For a complete citation please refer to the literature cited after the body of the report.

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